A History of Forest and Shade Tree Pest Management in Massachusetts

by David E. Leonard and Charles M. Burnham

Massachusetts Department
of Environmental Management

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PREFACE

We have attempted herein to describe the history of forest pest problems and summarize efforts of the Commonwealth to combat them. We devote much of the report to gypsy moth; necessarily so, since it is the insect that compelled Massachusetts in 1890 to conduct the largest attempt undertaken to exterminate a foreign insect pest. When the extermination program failed, a massive effort to control and contain the spread of the gypsy moth continued, with assistance by the U.S. Department of Agriculture. Included in these efforts was the largest attempt undertaken to import parasites, predators, and pathogens from Europe and Asia.

When the browntail moth appeared in Massachusetts in the 1890's efforts to contain it were meshed with the gypsy moth program, since both insects share similar habits and host preferences. For several decades the browntail moth was as serious a pest as the gypsy moth, but it now occurs only on the tip of Cape Cod and on Plum Island in Newbury.

Cost for control of gypsy moth exceeds that spent for any other pest of forest and shade trees. Periodic outbreaks of gypsy moth have defoliated areas of Massachusetts for more than 125 years, including nearly three million acres in 1981.

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Introduction

Introduction. Forests are the dominant feature of the Massachusetts landscape, with 3,225,000 acres, or 64% of the State forested. Efforts to preserve forest land for public use began in the 1890's. Massachusetts, through purchase and donation, now has more than 280,000 acres administered by the Department of Environmental Management, including 88 state forests, 65 state parks, and 18 state reservations.

Some woodlands are managed to provide forest products such as lumber, but less so than in the past. As suburbia expands, wooded areas provide much of the available land for homes. The increase in usage of forests for recreation and home sites exposes more people to periodic ravages of insects.

Forests provide valuable resources for birds, wildlife, watersheds, cleansing of air, recreation, and esthetics. They also provide necessary resources for insects and microorganisms. Most of these organisms are innocuous, and serve an invaluable role in decomposition, recycling energy resources, and maintaining the vitality and vigor of the forest ecosystem. A small percentage, however, can undergo outbreaks that provide dramatic and deleterious consequences to forests and the animals that inhabit them.

Exotic Pests. Often the most destructive pests are exotic, or introduced species for which no natural defenses exist for native trees. Two introduced tree diseases, chestnut blight from the Orient and Dutch elm disease from Europe, have eliminated or greatly reduced two of the most stately trees in North America, the American chestnut and American elm. The loss of these trees dramatically changed the composition and characteristics of Massachusetts forests and municipalities.

Exotic insect pests can reach enormous numbers where suitable food is available and climatic factors are favorable. The severity of outbreaks can dwarf those experienced in their

native range where they have co-evolved with natural control factors such as parasites and predators that help keep their numbers in check.

The Boston area was the point of entry for several exotic insect pests, including three tussock moths, gypsy moth, browntail moth, and satin moth, as well as beech scale, oriental moth, and larch sawfly. Beech scale, with the associated nectria fungus disease, now threatens the permanent loss of natural stands of beech. Another introduced insect, the hemlock woolly adelgid, is spreading in Massachusetts and killing hemlock.

State Agencies Responsible for Forest Pest Management. The responsibility of a State agency of the government to control forest pests originated in 1880. An Act of the Massachusetts Legislature charged the State Board of Agriculture with the extermination of the gypsy moth. Funding, which ended in 1900, resumed in 1905 with A. H. Kirkland appointed Superintendent of the gypsy and browntail moth program. This responsibility transferred to the State Forester in 1909, then to the Department of Conservation in 1920.

The Department of Natural Resources, formed in 1954, included forest pest management in the Bureau of Insect Pest Control. The title changed in 1988 to the Bureau of Shade Tree Management and Pest Control. The new Bureau retained the traditional mandate for suppression of pests and new responsibilities to provide cities and towns with technical, consulting, and financial assistance in shade tree management.

Chapter 29 of the Acts of 1995 abolished the Bureau of Shade Tree Management and Pest Control. Program functions transferred to the Bureau of Forestry in the Department of Environmental Management. Personnel were divided between two programs, Forest Health and Urban Forestry. The

Urban Forestry Program provides grants to municipalities for planning, education, tree maintenance and planting, funded under the federal Urban Forestry Program. The Forest Health Program participates in the National Forest Health Monitoring Program, initiated in New England in 1990 to monitor and document long term changes in the condition of forests.

The Forest Health Program currently has five district supervisors responsible for monitoring, assessing, reporting, and managing the stresses of the forest and shade tree resources of the Commonwealth and managing pests on lands administered by the Department of Environmental Management. Municipalities faced with insect outbreaks are provided predictions of the severity of the outbreak, information on the pest management alternatives available, and assistance with development and implementation of environmental impact statements necessary for use of approved pesticides.

Forest Health Program personnel also assist municipalities with development of spray contracts, delineation of the areas to be treated excluding sensitive areas such as waterways, supervision of the spray program, assessing the effectiveness of the treatment, and assisting with securing any State and federal dollars allocated to defray the costs of treatments.

The legislative mandates for forest pest control changed over time. Gypsy moth was the original charge, with browntail moth added in 1897. Other pest infestations were surveyed, but control responsibilities remained with gypsy and browntail moths until 1937, when eastern tent caterpillar was added by the Legislature. Control of Dutch elm disease was added in 1952, and additional responsibilities were added as new insect problems arose.

Chapter 2.

The Gypsy and Browntail Moths Arrive in Massachusetts

The two momentous events that shaped the importance of management of forest insect pests in Massachusetts, were both the results of the introduction of exotic insects. The first event occurred when the gypsy moth, *Lymantria dispar*, escaped in 1868 or 1869 from the Medford home of Leopold Trouvelot. Mr. Trouvelot, a visiting professor of astronomy at Harvard and an amateur naturalist, imported gypsy moths from France in the vain attempt to breed a hardy silk worm.

Modern concepts of genetics would later demonstrate the futility of attempting to interbreed the gypsy moth with other silk moths. Furthermore, the status of gypsy moth as a common and serious pest in forests and orchards in Europe and Asia made it a risky choice for experimentation. When he realized that his insects had escaped, Leopold Trouvelot attempted to find them. Failing to do so, he dutifully gave public notice of the escape, recognizing the potential for damage if the gypsy moth became established. His warnings, however, went unheeded.

The second event was the accidental introduction of a related tussock moth, the browntail moth, *Euproctis chrysorrhoea*, most likely in a shipment of roses from France or Holland around 1892 to a greenhouse in Somerville. When first identified in 1897, the browntail moth was causing extensive defoliation in about a two mile diameter area in Somerville. A close relative of the gypsy moth, the browntail moth shares similar preferences for a wide array of species of trees and shrubs. The browntail moth, however, has a noxious attribute affecting public health: hairs of caterpillars cause a severe and intensely itchy rash.

Chapter 3.

Life Histories of the Gypsy Moth and Browntail Moth

Life History of the Gypsy Moth. The gypsy moth has four stages of development, egg, caterpillar, pupa, and adult (Figure 1) and has one generation a year. Adult moths differ, with males primarily brown, and females white. Female gypsy moths from Europe (as was the introduction into Massachusetts) have wings, but do not fly. Male moths are active fliers, and are attracted to females for mating by a chemical (pheromone) released by females.

Female moths lay a single cluster of eggs (egg mass) in July, covered with chamois-colored hairs from her abdomen. The hairs give the egg mass a spongy appearance. Egg masses are usually laid in close proximity to where the female emerged from its' pupa, commonly on the trunks and beneath the larger branches of trees. Females also deposit egg masses in cryptic places such as in stone walls and under leaves on the ground. An egg mass from a well-fed, healthy female can contain 1200 or more eggs, but most masses contain about half that number.

The insect overwinters in the egg stage; hatch of caterpillars begins when trees begin to foliate in spring. The blooming of shad bush is often used as an indicator of when hatch should occur. Caterpillars grow by molting, a process of shedding their skin or outer skeleton. A male gypsy moth caterpillar has four, and a female five molts, resulting in full-grown caterpillars of two to three inches long. The larger caterpillars are gray, hairy, and have a paired row of red and blue spots on their back (Figure 1). As they grow, caterpillars consume more foliage, and when high numbers of caterpillars occur, they consume all foliage (defoliation). When development of the caterpillars is completed, they seek sites in which to pupate. The pupal period, in which transformation to the moth stage occurs, lasts about two weeks.

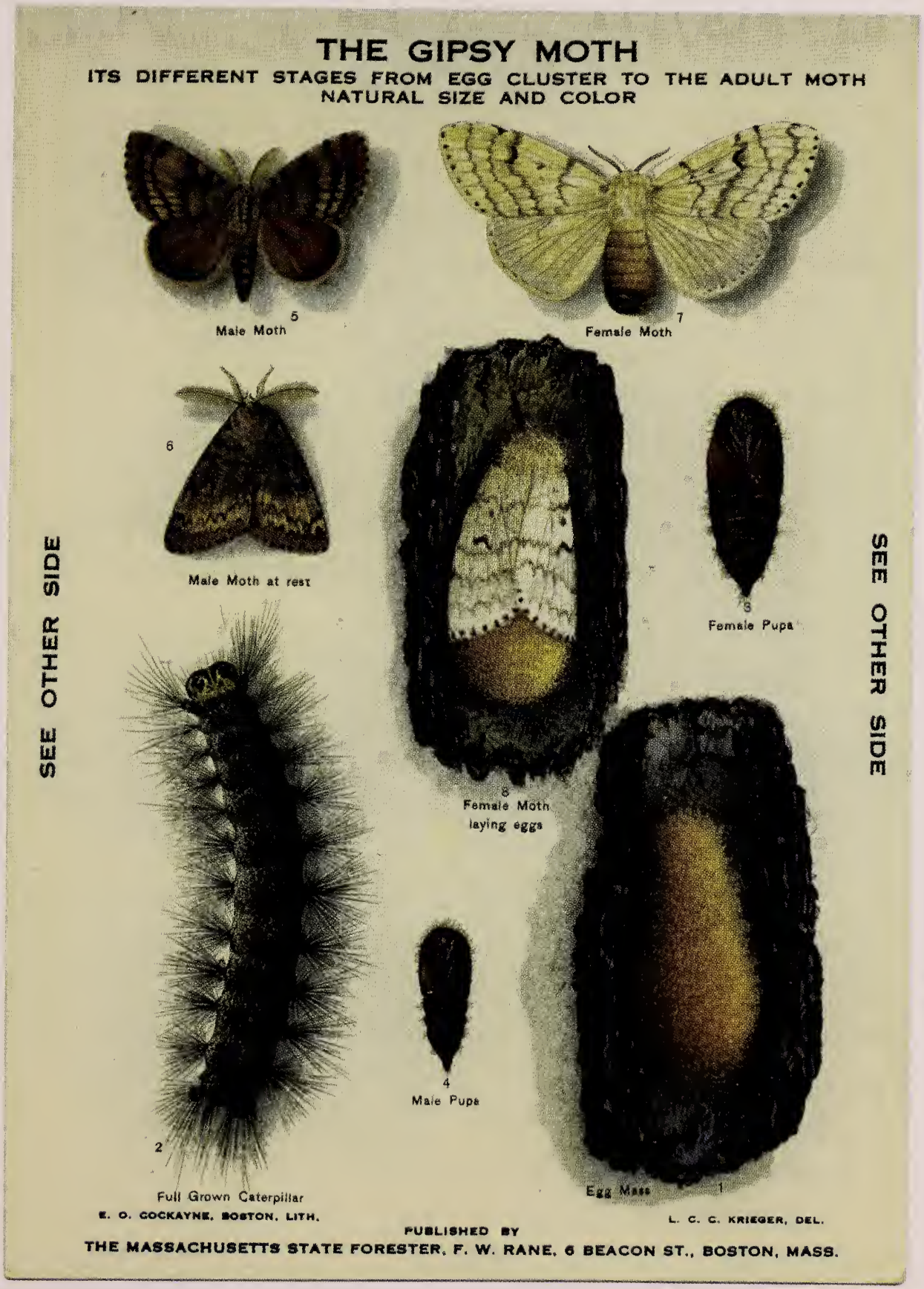


Figure 1. Life stages of the gypsy moth from a postcard printed about 1912 by the Massachusetts State Forester.

One of the factors that enhances the status of the gypsy moth as a pest is the wide range of hosts on which caterpillars can feed. This list includes over 300 species of deciduous trees and shrubs, with fruit trees and oaks among the favored hosts. Species of oaks are a common component in many Massachusetts forests. Many of the favored hosts include trees and shrubs commonly used as shade trees or ornamentals. Larger caterpillars will feed on conifers such as white pine. Normally, deciduous plants can survive one or two years of defoliation, but a single defoliation kills conifers.

Adults of most species of insects extend their range (disperse) by flying. With gypsy moth, dispersal occurs by a novel mechanism: newly hatched caterpillars hanging on threads of silk are caught up and carried by wind (ballooning). Although several reports indicate wind carries newly hatched caterpillars for 20 or more miles, the distances traveled are normally much shorter. Dispersal over long distances occurs with the transport of egg masses on vehicles.

The gypsy moth undergoes outbreak cycles of about nine years, and as numbers increase during the last several years of an outbreak, defoliation occurs. Most tree mortality occurs in weakened or suppressed (understory) trees. Outbreaks end with massive levels of caterpillar mortality caused by the virus disease of the gypsy moth.

Life History of the Browntail Moth. The life stages of the browntail moth are the same as the gypsy moth (Figure 2) but the life history and appearance differ. Browntail moth has one generation per year. Small caterpillars winter inside silken webs constructed on branch terminals. In spring, caterpillars emerge from these communal webs to feed on buds and new foliage. Caterpillars reach a size of one to one and one-half

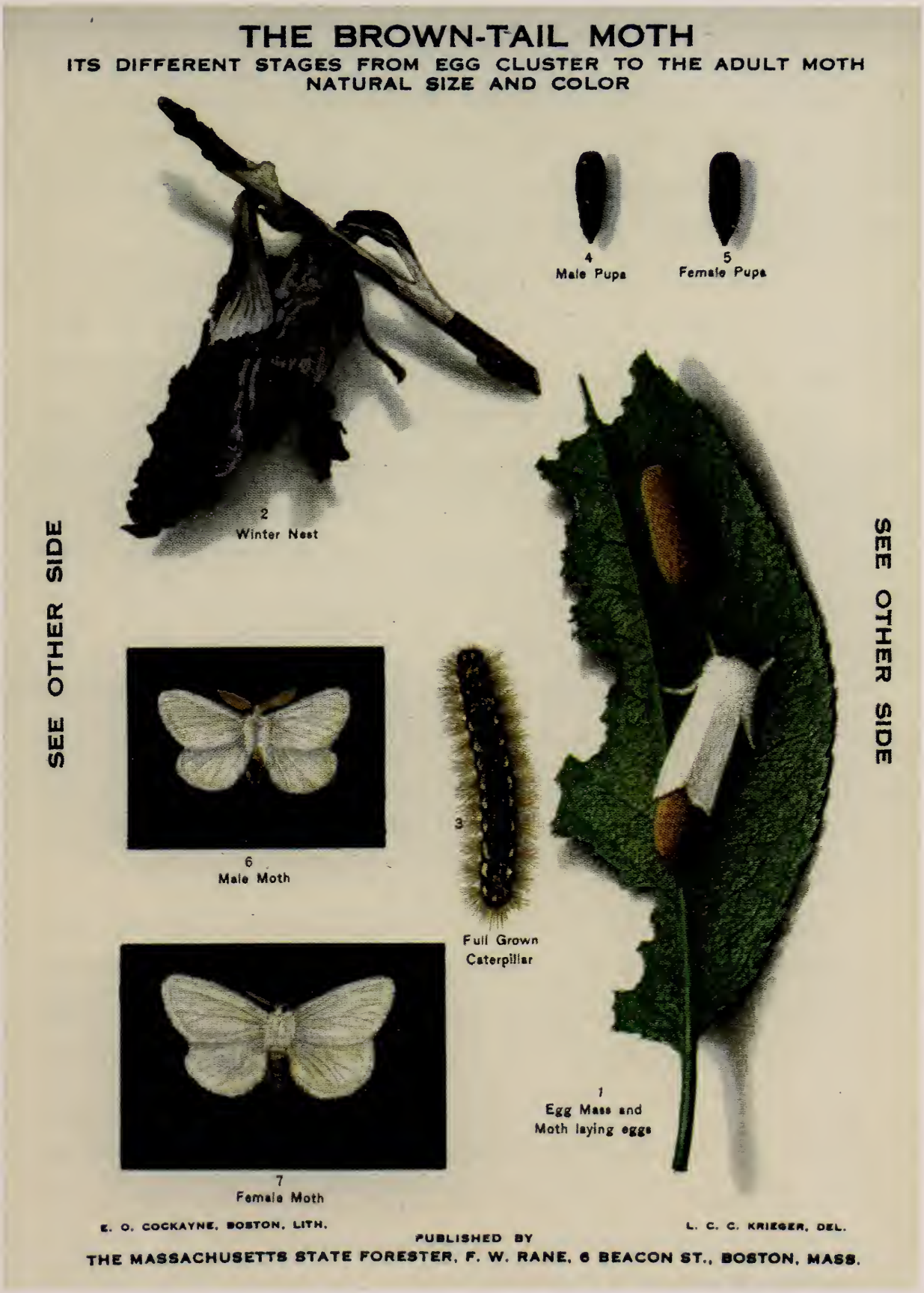


Figure 2. Life stages of the browntail moth from a postcard printed about 1912 by the Massachusetts State Forester.

inches and are brown, with two faint, broken white lines along the back and two red spots near the tail end (Figure 2). Caterpillars pupate in June and moths emerge in July. Moths of both sexes are white, active fliers, and can disperse long distances, particularly when aided by wind.

Female moths attract males for mating with a sex pheromone and produce a single cluster of about 300 eggs, covered by their abdominal hair. The eggs, laid on leaves of a suitable host plant, hatch in about a month. The new caterpillars are gregarious, and feed for several weeks before spinning the silken webs in which they remain until spring. The webs, or 'flags', serve as the primary means to detect infestations and are most visible after leaf-fall. Clipping and destroying webs is a common method of control.

Caterpillars emerge from webs in spring to feed on buds and new leaves. The wide host range is similar to the gypsy moth. Browntail moth caterpillars prefer a number of species of fruit trees (and roses), but also feed on a wide range of forest and shade trees.

Caterpillars have patches of tiny, barbed hairs containing toxins. When the hairs contact skin, they penetrate, break, and release allergenic toxins that cause an intense and itchy rash. The skins (exuviae) of caterpillars shed during molting retain these hairs. Light, and easily blown by wind, the exuviae increase the chance of exposure and rashes. During the early outbreaks, physicians and pharmacists were busy treating patients and dispensing lotions for relief of the eczema caused by the toxic hairs.

Chapter 4.

Early Histories of the Gypsy and Browntail Moths in Massachusetts

Early Experiences with the Gypsy Moth. Gypsy moths quickly became a localized nuisance after their escape from the Trouvelot home in Medford. The first large outbreak in 1879 demonstrated their destructive nature and heralded the yearly events of such occurrences in Massachusetts (and, subsequently, elsewhere in eastern North America). In addition to the discomfort, losses, and costs to individuals, the public expenditures at all levels of government to control and contain the gypsy moth have been enormous.

The definitive account of the early history of the gypsy moth in Massachusetts, published in 1896 by E. H. Forbush and C. H. Fernald depicts the seriousness of the problem:

> **"The number of caterpillars that swarmed over certain sections of the town during the latter part of June and most of July, 1889, is almost beyond belief. Prominent citizens have testified that the 'worms' were so numerous that one could slide on the crushed bodies on the sidewalks; and that they crowded each other off the trees and gathered in masses on the ground, fences and houses, entering windows, destroying flowering plants in the houses, and even appearing in the chambers at night. The huge, hairy full-grown caterpillars were constantly dropping upon people on the sidewalks beneath the trees, while the smaller larvae, hanging by invisible threads, were swept into the eyes and upon the faces and necks of passers. The myriad's that were crushed under foot on the sidewalks of the village gave the streets a filthy and unclean appearance. Ladies passing along certain streets could hardly avoid having their clothing soiled, and were obliged to shake the caterpillars from their skirts. Clothes hanging upon the line were stained by the larvae which**

dropped or blew upon them from trees or buildings. In the warm, still summer nights a sickening odor arose from the masses of caterpillars and pupae in the woods and orchards, and a constant shower of excrement fell from the trees. The presence of this horde is assuming the aspect of a plague."

Because of this "plague", trees and shrubs died, some after the first defoliation, with the more hardy dying after the second or third year of defoliation. Dead and denuded trees and shrubs gave the aura of January in July, and those wishing to escape the outbreak found no home-buyers willing to endure the gypsy moth.

People in the Medford area struggled with the pest for a decade. It was not until 1889, however, that Professor H. T. Fernald identified the pest as the gypsy moth. Dr. Fernald was an entomologist with the Hatch Experiment Station at the Massachusetts Agricultural College in Amherst (later, the University of Massachusetts, where a building is named in his honor). Dr. Fernald served as the leading entomologist during the early years of the gypsy moth program.

Concerns raised by the citizens of Medford resulted in the town meeting approving an increase of $300 in the appropriation for shade trees to hire men to scrape and burn gypsy moth egg masses. The $300 was the first public expenditure for control of gypsy moth, a minuscule amount in comparison with the many millions of dollars to follow.

The Massachusetts Program to Exterminate the Gypsy Moth. Recognizing that all towns now infested would need attention, Dr. C. H. Fernald and W. R. Sessions, Secretary of the State Board of Agriculture, urged selectmen to petition the General Court (Legislature) to authorize the State Board of

Agriculture to exterminate the gypsy moth. Petitions were sent from most neighboring towns, the State Board of Agriculture, the Massachusetts Horticultural Society, and the Essex County Agricultural Society. The petitions resulted in a Legislative Act to "Provide Against Depredations by the Insect Known as the Ocneria Dispar or Gypsy Moth" on March 14, 1890 and an appropriation of $25,000. Governor Brackett stated in his message to the Legislature:

> **"A new enemy is at present threatening the Agriculture, not only of our own State, but of the whole country. It is the gypsy moth, said to attack almost every variety of tree, as well as the farm and garden crops. The pest is spreading with great rapidity, and, if its eradication is to be attempted, immediate measures are of the utmost importance."**

The Act provided a Commission to Exterminate the Gypsy Moth comprised of three salaried persons. The initial survey of the Commission found the gypsy moth within a radius of 50 square miles, far exceeding the area previously thought to be infested. The Commission's request for an additional $25,000 was approved. Eighty-nine men were employed during the summer to spray trees with an arsenic insecticide, Paris green. They also patrolled highways to prevent spread of gypsy moth on vehicles, burned caterpillars, and cut and burned infested trees and bushes. Egg masses were scraped from trees in Medford, Malden, Somerville, Arlington, Everett, Cambridge, and Chelsea.

The efforts in 1890, however, did little to stem the spread of the gypsy moth from shade trees and orchards into forested areas. The Governor replaced the Commission to Exterminate the Gypsy Moth with three unsalaried members, and requested the program be placed under the control of the State

Board of Agriculture. The Board of Agriculture was provided full authority to conduct the program, including access to any lands infested. The Legislature appropriated $50,000 for the 1891 program to exterminate the gypsy moth.

A more vigorous attack was mounted, but the task was daunting, since the outbreak was still raging. Much of the effort was in destroying egg masses and spraying with Paris green. Paris green, however, had little affect on larger caterpillars. The infested area expanded to about 200 square miles by the end of the year.

Results in 1892 were more encouraging. The $75,000 appropriated by the Legislature resulted in efforts to spray small caterpillars, more readily killed by Paris green, and to band trees with strips of burlap and kill caterpillars that clustered beneath. Painting egg masses with creosote replaced scraping and burning as a quicker and more effective technique to kill eggs.

During the early years the program faced two major problems, to stem the destruction and spread, and to learn the life history traits of an insect previously unknown in the United States. Dr. C. H. Fernald directed the biological studies. A laboratory and insectary was constructed in Malden in 1895 to supplement biological experiments and insecticide studies conducted at the Massachusetts Agricultural College in Amherst.

The Legislature appropriated $100,000 in 1893, less than the $165,000 request of State Board of Agriculture. Funding wasn't received until mid-April, causing the lay-off of much of winter work force engaged in creosoting egg masses and conducting egg surveys to establish the boundaries of the infestation. Many of the men released when funds were expended found work elsewhere, thus necessitating the hiring

and training of new personnel when funding was again made available. The time required to train new personnel caused delays in surveys, destroying egg masses, banding trees with burlap, and initiating spray programs.

Eight hundred colonies were exterminated in 1893, with efforts concentrated in the outermost towns in the infested area. The interior towns were neglected for lack of personnel. The gypsy moth continued to move into woodlands where efforts of eradication would be more difficult.

The program grew to be the largest attempt to eradicate a foreign pest in North America. Prominent entomologists from the federal government and neighboring states were invited to review the program during the summer of 1893. The entomologists were aware of the consequences of the establishment and subsequent spread of gypsy moth to neighboring states.

The entomologists' reports marveled at the scope of the program, the leadership necessary to organize the large and ambitious program, and the commitment of the Commonwealth to provide funding. They raised concerns about the following problems: the pockets of infestations that remained over a wide geographic area; the invasions into forests which would require more personnel; and the possibility that the Massachusetts Legislature would not appropriate sufficient funds to exterminate the gypsy moth.

The Board of Agriculture received a legislative order in January, 1894, to provide data on the total funding appropriated thus far and an estimate of cost and time required to complete the extermination program. The Board responded that $275,000 was appropriated between 1890 and 1893, and $340,000 would be required to complete the program over the next five years. This $340,000 estimate, however, did not in-

clude costs to conduct surveys to insure no additional populations were present after the program ended.

The Board of Agriculture reorganized the Committee charged with the gypsy moth work to a six member Commission to Exterminate the Gypsy Moth in February, 1894. The Commission's role expanded to include matters relating to other insects and birds. As with the previous year, the Board of Agriculture requested $165,000, but received an appropriation of $100,000. Funds received in late May were too late to retain workers to destroy eggs and initiate spray programs against small caterpillars to reduce the spread of emerging caterpillars 'ballooning' on currents of wind. New personnel needed to be hired and trained.

The new Commission expressed concern that insufficient funding and lateness of appropriations seriously hampered the program, and if such continued that the work should be discontinued: this complaint would echo in following years. Because of the late start, the major effort was killing large caterpillars under burlap bands with a force of 265 men. Surveys conducted in the fall and winter showed many woodlands now infested.

The summer brought the first use of a new insecticide developed specifically for gypsy moth control. F. C. Moulton, a chemist employed by the Committee, formulated the insecticide, arsenate of lead. Arsenate of lead was more effective than Paris green in killing caterpillars, and was the insecticide most used during the next five decades. The development of this new insecticide was one of several new inventions and innovations for insect control developed by personnel working on the project.

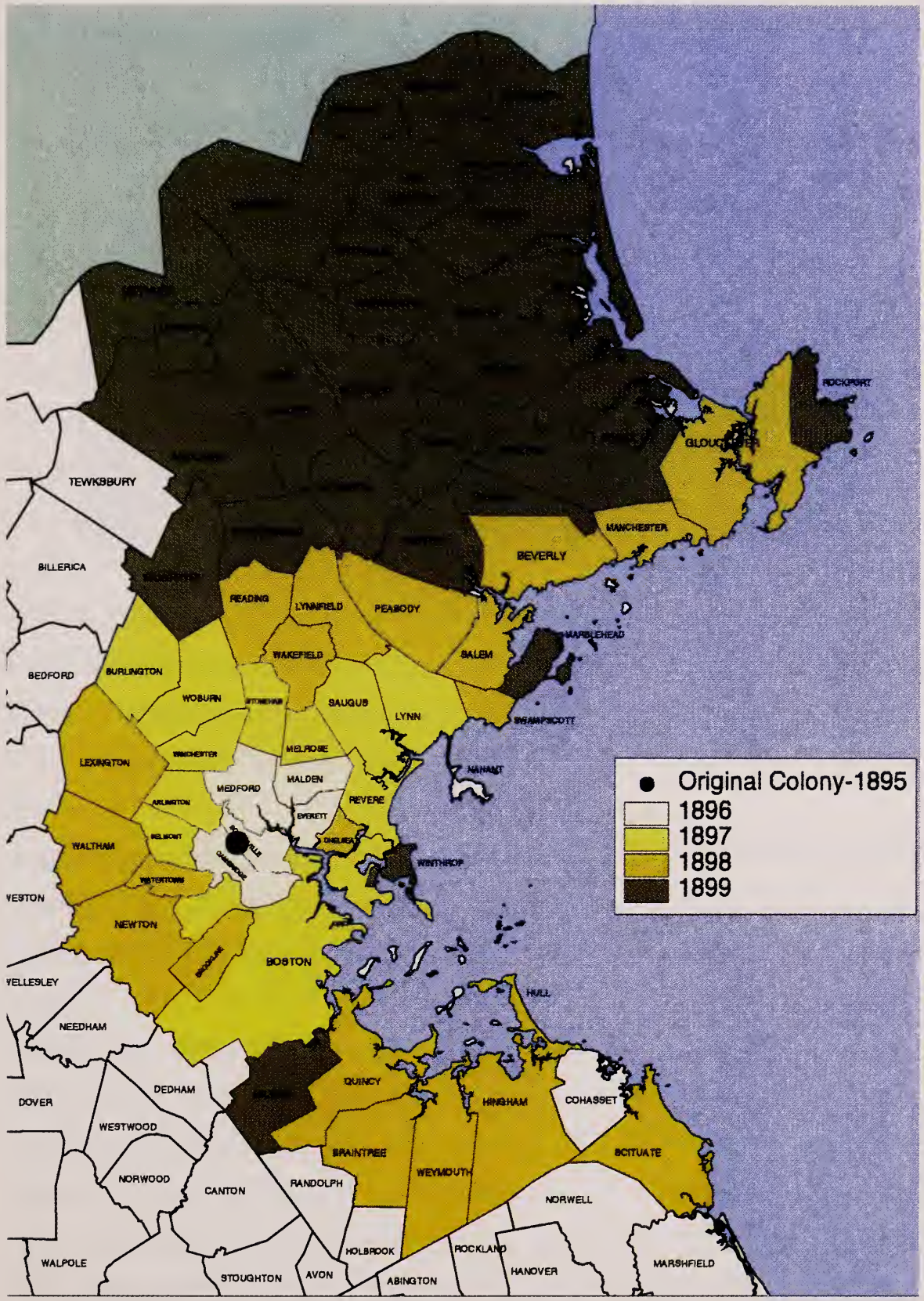
The most crucial year, perhaps, for the effort to exterminate the gypsy moth was 1895. Faced with the continued

Spraying nozzles, tank and truck.

Figure 3. Early spray apparatus used for gypsy and browntail moth control. The hand-operated pump provided sufficient pressure to reach all but the tops of the largest trees.
From the 46th Annual Report of the State Board of Agriculture, 1898.

shortage of funding from the Commonwealth, a delegation went to the United States Congress but failed in their quest for federal funds. The Board of Agriculture request to the Legislature for $200,000 raised some opposition. After public hearings with support by citizens from the infested towns, $150,000 was appropriated.

Again, funds were not available until mid-May. The unusually mild spring and early summer caused the rapid development of caterpillars, shortening the period for control



Map showing the rapidly increasing spread of the brown-tail moth.

Figure 4. Early spread of the browntail moth in Massachusetts from the site of its introduction in Somerville. From the 47th State Board of Agriculture Report to the Massachusetts Legislature, 1899.

Figure 5. Crew clipping webs during an early outbreak of the browntail moth. Webs were burned to kill the caterpillars wintering inside. From a glass lantern slide photograph, Massachusetts Department of Environmental Management.

efforts. Defoliation now occurred in large tracts of woodlands. The gypsy moth ranged from Lexington to the ocean. Exterminating was a lost cause; future efforts would be to contain the spread.

During the next several years the program continued with funding levels from the Legislature of about $150,000 per year. As before, funds came too late to maintain continuity in the program. The boundaries of the infested area continued to expand. Creosoting egg masses, banding trees and killing larvae, and spraying with arsenate of lead continued as the primary techniques for control, but new methods were adopted. Raupenlein (caterpillar glue), a sticky concoction of printers ink and gas tar developed in Germany, was placed on tar paper bands on trunks to prevent caterpillars from climbing trees. Flame throwers (cyclone burners) were used to burn ground

litter and stone walls to kill eggs.

Sprayers were cumbersome, and required several men to operate. They consisted of a wooden tank mounted on wheels (Figure 3). The tank held 100 gallons of spray mixture and the pump, mounted inside of the barrel, was operated by a lever. Fully loaded, the spray apparatus weighed about 1,000 pounds, and was pulled by hand.

Appearance of the Browntail Moth, 1897. Besieged by, and fighting a losing battle against the gypsy moth, a new problem arose. An overseas shipment of nursery stock or roses to a greenhouse in Somerville early in the 1890's contained browntail moth. Defoliation, particularly of fruit trees, was noted in the vicinity of the greenhouse for several years prior to 1897. When the browntail moth was identified in 1897 as the cause of the defoliation, the infestation covered an area of about two square miles in Somerville, with smaller infestations in Malden, Everett, and Medford.

The extent of the damage was reminiscent of the gypsy moth. The browntail moth, a tussock moth closely related to gypsy moth, shares a similar wide range of preferred trees and shrubs. Early publications on insects in Europe listed browntail moth as a pest, particularly of orchards. In their 1903 report on the life history and habits of the imported browntail moth, C. H. Fernald and A. H. Kirkland quote William Curtis on the epic 1782 outbreak in London:

> **"...the inhabitants of London and its vicinity were thrown into the utmost consternation...whole plantations of fruit trees, as well as trees of the forests, shared the general havoc, presenting their leafless branches in the midst of summer as though stricken and destroyed by the blasts of winter. An appearance so extraordinary was calculated to create terror; it was**

naturally interpreted as a visitation from heaven, ordained to destroy all the sources of vegetable life, to deprive man and cattle of their essential food, and finally leave them a prey to famine."

The appearance of yet another introduced defoliator in Massachusetts was alarming, but the health aspects of contact with browntail moths raised another concern. The eruption of intensely itchy rashes on all parts of the body exposed to the irritating hairs from larvae and their wind-blown cast skins was more serious than exposure to poison ivy or poison oak. People with light complexion suffered the most from the rash. Rubbing alcohol, one of the early remedies, is an effective means of reducing itchiness.

Fernald and Kirkland also provide testimonials about the severity of the rash caused by browntail moth including the following account:

"I was painting a house...in July, 1897. There were some caterpillars on the trees and many webs containing cocoons. Some of the branches were so near the house we were obliged to cut them off. The house was covered with cocoons also; we found them under the clapboards, and of course had to brush them off. My wrists and arms were poisoned, and soon became a sight. Some of my men were also badly affected, and all of them were more or less poisoned. It was terrible, —simply terrible! I had to go to a doctor for relief, and he gave me an ointment to allay the irritation. A neighbor of mine whose family had suffered severely from the poison of the brown-tail moth suggested the application of alcohol, as it had relieved her.

This neighbor stated that each week they were freshly poisoned by the clothes, which, hanging on the line, came in contact with the hairs of caterpillars; as a result, the skin was irritated when the clothes were worn.

In my case, not only were my arms and wrists poisoned, but my whole body The alcohol allayed the irritation so that I could get a little sleep, but the trouble lasted over a month, and was simply torture, the heat greatly intensifying the suffering. If I had known about it, I would not have painted the house for double the price of the job."

Efforts Against the Gypsy and Browntail Moths Combined as the Moths Program. Alerted to the seriousness of this new insect pest, the Legislature redirected $10,000 in 1897 from the gypsy moth program to gather and destroy winter webs of the browntail moth in the fall. This plan was doomed, however, when a strong southerly gale occurred after the moths appeared, carrying them northward. Rather than remaining in the Somerville area the browntail spread over several hundred square miles, an area nearly as large as that infested by gypsy moth. This experience demonstrated the great potential for dispersal, and nullified all hopes of eradicating the browntail moth. The Legislature combined efforts to control and contain the browntail moth with gypsy moth as the Moths Program. Most of the efforts, however, were directed against the gypsy moth.

During the next three years, the browntail moth spread to nearly four times the area that it took the gypsy moth to infest in 40 years (Figure 4). Prevailing winds during moth flight determined the spread to the North and East. The control practices most used were destroying winter webs

(Figure 5), spraying with arsenate of lead and, in later years, by seeding infestations with the fungal pathogen obtained from Japan (see Chapter 9).

The Legislature appropriated nearly one million dollars for gypsy moth control between 1893 and 1900 (this sum did not include expenditures by municipalities, the federal government, or individuals). The program was large: in 1899, for example, it employed more than 500 men during the summer. Fifty-three tons of burlap, bought by the train car load, was cut into bands and placed on over 2,300,000 trees. These, along with the 1,000,000 bands still serviceable from previous years, required inspection at two or three day intervals to kill caterpillars underneath. Twenty gangs of men operated spraying equipment. The Moths Program maintained meticulous records. The summary of the year's work in 1899 included the following

Trees inspected 17,487,105
Trees banded with insect-lime 301
Trees banded with burlap 2,304,552
Trees sprayed with arsenate of lead 10,752
Trees cut 468,790
Trees trimmed 99,597
Trees in which cavities were covered 8,896
Buildings inspected for egg masses 9,554
Yards of fences inspected for egg masses 274,197
Yards of stone walls inspected 89,765
Yards of stone walls burned 11,219
Yards of stone walls sprayed 19,222
Acres of brush cleared and burned 2,559
Acres of ground burned over with oil 151
Acres of ground burned over without oil 155

Scattered infestations occurred in 34 infested cities and towns at the end of 1899, with the gypsy moth at the lowest ebb since the beginning of the program. The Commission was confident that extermination of the remaining infestations was now possible.

The large, publicly funded Moths Program was not immune to criticism. The Legislature terminated the program in 1900, as a result, in part, of a unfavorable report of a legislative committee. The report cited waste, complaints of disgruntled former Moths Program employees, little significant threat of the gypsy moth, and low numbers of gypsy moths at the end of the 1899 season.

The Gypsy Moth Committee spent considerable time and effort since 1891 as unpaid individuals on the Board of Agriculture. Funding for their program often occurred late, and was less than requested. The Committee concluded in their report of 1900:

> **"The Board of Agriculture has done its work. The State of Massachusetts, who, through its Legislature, stopped the work when "not a large colony" could be found and when extermination was in sight, has taken upon itself the responsibility, and there let it nest. This Board has no apologies to make; it has given its best efforts and done its best work from the beginning to end. It has given this work into the hands of a carefully selected committee. Their reward and its reward are the benefit to the people. One day in each fourteen has been set apart by this committee for careful investigation and consideration of means, methods and results. It looked forward confidently to the laurels that would crown its successful issue, -the greatest work of this kind ever laid upon a board, or accom-**

plished by a Commonwealth for the future good of a nation."

Hiatus in Control Programs, 1900-1904. The low numbers of gypsy moth in 1899 were the results of the intense control efforts and most likely a low ebb in the natural eight or nine year cycle of abundance in gypsy moth. The ebb was short-lived; the prophetic claims of the Committee were quickly realized. During the next two years, populations of both the gypsy and browntail moths exploded, with the gypsy moth now found from Waltham to the sea, and the browntail moth had spread into southern portions of Maine and New Hampshire. The concern about spread of gypsy moths into neighboring states was realized, with an infestation covering four or five miles discovered in 1901 in Providence, Rhode Island. The Rhode Island infestation was thought the work of a malicious or irresponsible person.

Chapter 5.
Re-birth of the Moths Program

1905-1910. No longer able to ignore the scope and severity of the outbreaks of the moths, the Massachusetts Legislature appointed A. H. Kirkland as Superintendent for Suppressing Gypsy and Browntail Moths and appropriated $300,000 for the period of 1905 to 1907. The browntail moth spread westward beyond Worcester and was well established in southern portions of New Hampshire and Maine. The range of gypsy moth, found in 1900 in isolated localities in 359 square miles in Boston and surrounding towns, burgeoned to 2,083 square miles, including much of eastern Massachusetts, southern Maine and New Hampshire. Isolated infestations of gypsy moth were now in Connecticut as well as Rhode Island. The Committee on Gypsy Moth, Insects, and Birds recommended that the Board of Agriculture petition the U.S. Congress for federal aid since the gypsy moth was now a problem for other states as well as Massachusetts.

The gypsy moth spread to 2,500 square miles in 1906, infesting about one quarter of Massachusetts including the western portion of Cape Cod. The U.S. Congress provided $82,500 for suppressing gypsy and browntail moths in the New England States under the direction of Dr. L. O. Howard, Chief of the Bureau of Entomology and Plant Quarantine. The federal efforts included spraying and clearing brush and trees along infested roadways to contain the spread on vehicles.

The State sprayed shade trees and creosoted egg masses in badly infested municipal areas. Infested woodlands continued to be neglected for lack of funds. Horse-drawn sprayers were constructed with larger capacities for liquids and more powerful pumps (Figure 6). These machines had four cylinder engines and pumps capable of applying insecticide to the tallest trees.

Figure 6. Horse-drawn sprayer designed and built in 1909 for gypsy and browntail moth control. From the 8th Report of the State Forester to the Massachusetts Legislature, 1911.

The State and the Federal Bureau of Entomology developed an ambitions program to import parasites and predators. The first shipments from Europe in 1905 were maintained at the federal laboratory in Melrose Highlands to build numbers sufficient for release in gypsy and browntail moth populations (see Chapter 9).

Massachusetts employed 1200 and the federal program 100 men, respectively, during the winter of 1906. The total funding expended by Massachusetts, the federal government, municipalities, and individuals was estimated at between $500,000 and $750,000, and was considered to be the largest sum ever expended under legal authority for insect pest control.

The area infested by the gypsy moth in 1907 included most of Barnstable, Norfolk, and Middlesex Counties and all of Plymouth County. The western boundary was at Worces-

ter and Lunenburg. Gypsy moth was most numerous east of a line from Quincy to Newton, north to Waltham and northeast to Newburyport. The towns most seriously affected were Lexington, Woburn, Saugus, Lynn, Lynnfield, and Salem. The Moth Programs continued as in the past year, with the federal appropriation increasing to $150,000 for efforts in Massachusetts and other New England States.

The gypsy moth continued to spread through much of Cape Cod and westward to Springfield, where isolated infestations were found in 1908. State and federal programs continued as before. Forests continued to be neglected for lack of funding.

An act signed by Governor Draper in March, 1909, abolished the Office of Superintendent for Suppressing the Gypsy and Browntail Moths and transferred the responsibility to the State Forester, F. W. Rane. The Legislature provided $150,000 annually for three years. Mr. Rane reorganized the six divisions of the moth-infested area into fifteen districts. Each district had a supervisor provided with a motorcycle to cover the 12 to 15 towns in their jurisdiction. Control efforts for gypsy moth were the same as previously used, creosoting eggs, killing larvae under burlap bands, burning areas containing egg masses, and an increase in the use of arsenate of lead.

Larger and more efficient sprayers were designed and developed under the aegis of the program. By 1909, 200 hand sprayers (Figure 3) were still in use, but construction of power sprayers (Figure 6) increased to 150. About 100 tons of lead arsenate was applied on more than 7,000 acres using 10 pounds of arsenate per 100 gallons of water. About 700,000 trees were banded with burlap, and caterpillars beneath the bands were killed. Tanglefoot, a new sticky substance replaced the coal tar mixture previously used to prevent caterpillars from climb-

ing trees. Tanglefoot was placed in bands on more than 25,000 trees in 1909.

Colonel William D. Sohier initiated the first wide-scale, privately funded control program for gypsy moth in 1908. Col. Sohier organized a committee of wealthy summer residents of the North Shore who contributed funds to creosote egg masses and spray caterpillars. This work continued for several decades and successfully protected the summer residences from widespread defoliation.

Outbreaks in forests were now commonplace. As trees were defoliated, caterpillars migrated, often in huge numbers, to find new food. To contain this migration, 50 to 100 foot swaths were cleared of trees and brush and sprayed with arsenate of lead.

Recognizing that the efforts of the Commonwealth and the growing federal involvement would also require funding by cities and towns, a tax was devised by the Legislature in 1909. Smaller cities and towns were taxed 1/25 of 1 percent of their evaluation, and larger cities (valuation over $12.5 million dollars) $5,000. Towns received yearly surveys pinpointing infestations. If towns took no action they were billed from the tax for control efforts by State personnel. The failure of some towns to attempt control efforts often resulted in movement of gypsy moths into neighboring towns.

1911-1920. The State, federal and local governments, and individuals spent an estimated $5,500,000 for control efforts by 1910, yet areas infested with gypsy and browntail moths continued to expand. The program continued along lines already established, with an increase in efforts to build more efficient and larger spraying machinery since use of arsenate of lead was the most efficient way to kill caterpillars. Innovations and inventions by State personnel led to the development of

more efficient pumps and machinery, including in 1911 the first sprayer mounted on a truck.

Truck-mounted sprayers cut insecticide applications from $30 to $6 per acre in 1911, and their mobility resulted in an increase in the number of acres treated. Over 400 tons of arsenate of lead were applied for gypsy and browntail moth control. With fabrication of more sprayers, the use of arsenate of lead increased, from 750 tons applied in 1912 to 1 million tons in 1915. To reach wooded areas, high pressure pumps were developed that could maintain sufficient pressure for spraying with one mile of hose.

The role of the state was reduced as municipalities assumed more responsibility for control. After three years of appropriations of $150,000 per year, State costs were cut by $115,000 in 1913. The federal Bureau of Entomology assumed responsibility for preventing the westward spread of the gypsy moth, establishing a border zone in 1912 through the central part of Massachusetts. Eradicating the gypsy moth within the border zone was a federal responsibility.

The Federal Horticultural Board established regulations in 1915 under the Plant Quarantine Act for inspection of all plant material leaving infested areas. Shippers had to apply for inspections by federal inspectors, and all shipments required certification that the material being transported contained no gypsy moth. As time permitted, State personnel assisted with inspections.

Several changes occurred in the State program. Tree banding was discontinued in 1915 to eliminate the expensive costs of burlap and of personnel required to place, inspect, and kill caterpillars under bands. Savings provided additional funds for the purchase of arsenate of lead. Creosoting egg masses, another labor-intensive program, was dropped in 1916.

Forestry practices were initiated to reduce the number of favored host trees and to stock white pine, a more valuable tree species. State workers developed management plans and supervised landowners in removal of favored trees for cordwood; the sale of cordwood served as an incentive for the program.

The gypsy moth infested about one third of New England and browntail moth spread into the Maritime Provinces of Canada. Isolated infestations of gypsy moth appeared in New York State and Ohio, likely the result of transport of egg masses. Two infestations occurred in New Jersey. The most serious, in Somerville, covered about 420 square miles and was the first documented record of a second introduction of gypsy moth into North America.

The Somerville, New Jersey outbreak originated from a large shipment of infested blue spruce from the Netherlands. The situation was complicated by the more than 250 shipments of this blue spruce to 17 other states. Federal entomologists inspected each site where trees were shipped, and eradicated all gypsy moth infestations found. This work, and the efforts to contain the New Jersey outbreak, reduced the number of federal workers available for work in New England. The gypsy moth was eradicated in New Jersey by 1931 at a cost of about $2,500,000.

The First World War curtailed foreign exploration for parasites and predators, and caused a shortage of supplies, equipment, and personnel. Low temperatures during several winters killed browntail moth caterpillars and gypsy moth eggs exposed above the cover of snow. The program of removal of favored host trees became an economic boon as a shortage of fuels caused an increase in the value of cordwood. The practice of thinning favored host trees ended when cordwood prices

fell after the War.

1921-1930. Gypsy moth caterpillars damaged cranberries, the result of small caterpillars blowing into bogs. To determine the distance newly-hatched caterpillars could travel, federal entomologists placed screens on Race Point in Provincetown. The screens trapped newly-hatched caterpillars blown about 20 miles from the nearest infested area.

Female gypsy moths release a chemical (pheromone) that attracts males for mating. In 1921, female moths were attached to boards covered with a sticky substance to capture males attracted by the pheromone. This provided a crude, but quick survey method to locate infestations. A chemist at the Harvard Medical School attempted to identify the chemical produced by female moths, but it was many years later that the pheromone (disparlure) was identified and synthesized by federal scientists.

The browntail moth began a precipitous decline from the maximum range in 1914 of over 38,000 square miles extending from the Maritime Provinces of Canada to the eastern tip of Long Island, New York. By 1922, the only infested areas remaining under quarantine were Massachusetts and coastal portions of Maine and New Hampshire.

In contrast to the decline of the browntail moth, the area infested with gypsy moth continued to expand. The gypsy moth had been recorded from every city and town in Massachusetts by 1924, as well as in bordering states, Maine, southern Quebec Province, Canada, and New Jersey. The continuing movement westward caused the U.S. Department of Agriculture to shift the barrier zone from the central part of Massachusetts to Berkshire County.

Arsenate of lead continued as the primary insecticide. The washing from foliage by rain required re-spraying of some

areas. Research showed that the addition of linseed or fish oil at one quart per 100 gallons of spray mixture provided better adhesion during rainy periods. Trials were also conducted in 1926 to apply insecticide dust with an airplane.

The highest levels of defoliation by gypsy moth in the 1920's occurred in 1927 and 1928 (Appendix 1), mostly on Cape Cod and eastern parts of the State. Browntail moth occurred in small infestations in eastern areas of the Commonwealth. Reductions in appropriations from the Legislature caused some cities and towns to curtail control programs. Much of the defoliation was in forests, and the value of forest products did not warrant the cost of spraying. Privately funded work on the North Shore continued, still directed by Colonel Sohier.

1931-1940. Gypsy moth populations were low in 1931 and 1932, but increased and remained relatively high during the remainder of the decade, with nearly 400,000 acres defoliated in 1937 (Appendix 1). Outbreaks of gypsy moth were now common to eastern portions of Massachusetts, particularly on Cape Cod. In the early 1930's, the first large outbreaks appeared in Worcester County, and Hampshire and Hampden Counties experienced their first bouts of defoliation. About 95 tons of arsenate of lead was used in both 1937 and 1938.

State personnel assisted with a federal program in 1930 by collecting thousands of female pupae. When moths emerged, the tips of the abdomen of moths containing the glands producing pheromone were clipped, and an extract containing sex pheromone was produced. The pheromone extract placed on sticky boards to trap males was a useful refinement for gypsy moth surveys.

With the Great Depression approaching, and work scarce, a civil works project was started in November, 1930,

to help cities and towns with unemployment and welfare problems. The project hired 1350 men to creosote egg masses in the fall in 233 cities and towns east of the Connecticut River. The Civilian Conservation Corps (CCC) established camps in Berkshire County for young, unemployed men to assist with gypsy moth control projects in 16 towns. The National Industrial Recovery Act of 1933 allocated over $2,000,000 for gypsy moth control in New England, New York, and Pennsylvania. Massachusetts received $389,000 for work in woodlands east of the Connecticut River.

Personnel of the Department of Conservation cooperated with most federally sponsored work projects. These projects greatly enhanced the amount of work possible. In 1935, for example, there were more than 2,000 miles of roads and nearly 750,000 acres of woods scouted for egg masses; 5,500,000 egg masses destroyed; 6,000 acres of woodlands thinned with the slash burned; and over 12.5 million larvae or pupae crushed. More than 750,000 browntail moth webs were destroyed in the eastern portion of the state in 1937. Works Progress Administration (WPA) funds employed more than 5,000 men, primarily to destroy over 1 million nests of tent caterpillars and over 400,000 browntail moth webs and to assist with spray programs. Funding was reduced, when the federal Emergency Conservation Work Program was phased out and some Civilian Conservation Corps camps were closed.

The Department of Conservation and the U.S. Department of Agriculture tested new approaches to apply insecticide by air. An airplane applied liquid insecticide in 1935 and an autogyro, the precursor to the helicopter, applied insecticide dust in 1936.

The law under which the Department of Conservation operated allowed only control of gypsy moth and browntail

moths, although outbreaks of other pests were monitored. The law was amended in 1937 to include $20,000 for control of the eastern tent caterpillar, but the money was not appropriated.

The destructive hurricane of 1938 blew down many trees, and surveys for egg masses were difficult. There was no evidence, however, that the hurricane caused spread of egg masses.

Chapter 6.

Moths Program and Advent of DDT

1941-1950. The relatively high levels of defoliation in the previous decade carried over into 1941 (Appendix 1). Following two years of low levels of defoliation, gypsy moth populations again increased. The mild winter of 1943 brought forth one of the heaviest outbreaks of gypsy moth in recent years, and included all of Cape Cod. Outbreaks occurred also in Hampden, Hampshire, and Franklin Counties. More than 450,000 acres were defoliated in 1945, the largest recorded since 1924, when defoliation surveys were initiated.

World War II affected control programs, bringing about the elimination of the WPA and a shortage of manpower. College women were hired during summers for work on the Moths Program. The gypsy moth was in a low ebb of its cycle. The browntail moth rebounded in Essex and Middlesex Counties, and eastern tent caterpillar increased in much of the State. The U.S. Department of Agriculture abandoned the barrier zone in Berkshire County and turned control efforts in the County back to the Commonwealth.

The Moths Program lost key personnel in 1942 with a combined 75 years of experience. Harry B. Ramsey, Chief Moth Suppressor for the Department of Conservation retired, as did A. F. Burgess, who had spearheaded the federal program for 35 years.

A new insecticide, DDT, was widely used during World War II, mostly to control insect vectors of human diseases. DDT was considered a miraculous new tool for insect control because it was cheap to produce, killed a wide spectrum of insect species, had long residual effectiveness, and had a low level of toxicity to mammals. Near the end of the War, DDT was available for testing on agricultural and forest pests, and was first tried against the gypsy moth in Massachusetts in 1945.

The excellent level of control with DDT exceeded ex-

pectations and renewed hopes that gypsy moth could be exterminated. This optimism, however, came before harmful properties of DDT were known. The slow degradation of DDT enhanced its residual effectiveness as an insecticide. Studies in later years, however, demonstrated that DDT remained in the environment for a long time and accumulated in the fat of animals, with deleterious reproductive consequences, particularly in birds.

The State, with cities and towns, spent nearly $800,000 for gypsy and browntail moth control in 1947, nearly all for DDT applied by airplanes. The Department's 1948 report suggested gypsy moth could be exterminated in five years by aerial spraying of DDT at a cost of $350,000 per year. The effectiveness of DDT appeared to justify the optimism for extermination in Massachusetts. In 1948, 250,000 acres on Cape Cod were sprayed with 1/2 pound of DDT per acre. There was no defoliation, and only seven male moths were trapped on the entire Cape. The numbers of ticks, mosquitoes, and biting flies were also were reduced.

During the ensuing years the acreage sprayed with DDT increased. The Bureau used a truck-mounted, portable facility to produce DDT insecticide formulations at reduced costs. The cost of producing and applying DDT was about 82 cents per acre. The entirety of Plymouth and Barnstable Counties were sprayed in 1949 and 500,000 acres were treated in Plymouth and Bristol Counties in 1950. The Legislature agreed to pay one-half of the cost of the aerial spraying of large areas provided the DDT was at sufficiently low strength that little or no damage to humans or warm-blooded animals ensued. The effectiveness of DDT and the amount of area sprayed in the last half of the decade reduced the number of acres defoliated (Appendix 1).

1951-1960. Following several years of low gypsy moth numbers, the amount of defoliation began to increase in 1952 and reached the highest level on record in 1953 of nearly 918,000 acres (Appendix 1). The following year, one million acres were sprayed with 9% DDT at the rate of 3/4 gallon per acre. More than 521,000 gallons of 9% DDT was applied at the same rate in 1955 on nearly 700,000 acres. DDT was used on 121,000 acres in Plymouth, Dukes, and Barnstable Counties in 1956 and 78,000 acres in Berkshire County in 1957. The areas sprayed were not defoliated, and during the latter half of the decade defoliation levels were amongst the smallest on record (Appendix 1).

As the acreage being sprayed increased, so did the number and size of airplanes, from single motor planes and helicopters to a four engine, surplus B-17 bomber used in 1954. State personnel continued to survey for gypsy moth egg masses, alert towns when populations were sufficient to cause defoliation, coordinated the development of contracts with aerial spraying companies, and monitored the spray operations.

The Massachusetts Legislature, for reasons of economy, withheld funds in 1958 for spray programs in two counties. This decision was most likely rooted in the growing pesticide controversy as studies began to document the environmental consequences of the wide-scale use of pesticides, particularly DDT. About three million gallons of spray containing DDT had been used in Massachusetts to control gypsy moth. Without matching funding from the State most municipalities opted not to spray; only 10,000 acres were treated in 1958.

Forest insect control was transferred from the Department of Conservation to the new Department of Natural Resources in 1954. The Chief Moth Suppressor, Harold L. Ramsey, became the Chief of the Bureau of Insect Pest Con-

trol. The assigned duties continued as control of gypsy moth, browntail moth, eastern tent caterpillar and Dutch elm disease control which was added in 1949. In cooperation with the Departments of Agriculture and Public Health, the eclectic mix of control of white pine blister rust, wood ticks, and poison ivy was added. These responsibilities were a departure from working solely on insect-related problems. Hemlock looper was added in 1955, with an appropriation of $100,000 to control an outbreak on Cape Cod.

A number of changes occurred in 1959. Harold L. Ramsey retired and was replaced by Charles (Stan) Hood. The plant at Stow used to produce DDT formulations was closed. A study was initiated with the Cooperative Wildlife Unit in Amherst to examine the effects of DDT on bird populations. Legislation was introduced to regulate the use of pesticides.

1961-1970. Gypsy moth populations, low since the mid 1950's, began to rebound with 150,000 acres defoliated in 1962 (Appendix 1). DDT at the rate of one-half pound per acre was used to treat gypsy moth and linden looper on 163,000 acres in Hampden, Hampshire, and Franklin Counties in 1963, and on about 7,000 acres for gypsy moth in Barnstable County in 1964. After 1963, when nearly 90,000 acres were defoliated, gypsy moth numbers declined. Levels of defoliation were low in the second half of the decade and no spray programs were conducted.

The controversies on the use DDT and other 'hard' pesticides were intensified with the publication of Rachel Carson's Silent Spring in 1962. Tests were conducted to find a suitable, more environmentally safe alternatives. The bacterial insecticide Bacillus thuringiensis was first tested in 1960 and Sevin (carbaryl) in 1961. Carbaryl was used to treat 22,400 acres on Cape Cod in 1965. The Pesticide Board of the Board of Pub-

lic Health banned the use of DDT, effective on 31 December, 1969.

Chapter 7.
Moths Program and Research

1971-1980. Gypsy moth populations remained relatively low in the first portion of the decade, but began to build in 1977. In 1980, 907,075 acres were defoliated approximating the record year of 1953 (Appendix 1).

The Bureau continued to seek alternatives to 'hard' pesticides, namely the microbial insecticide, Bacillus thuringiensis, carbaryl, a carbamate insecticide, and two organophosphate insecticides, gardona and phosvel.

The Department cooperated with the federal Forest Service on gypsy moth spray programs. These programs required an environmental impact statement and agreement of the towns involved, with the Forest Service bearing one half of the cost of the program.

Gypsy moth populations were relatively low during the decade, and there were few spray programs. About 24,000 acres were sprayed in Barnstable County in 1973 with carbaryl. Ground equipment was used to spray 110 acres in Wells State Park with carbaryl. About 15,100 acres were sprayed in Bristol and Norfolk Counties in 1978 using carbaryl at a cost of $3.32 per acre. Walpole sprayed 480 acres with Bacillus thuringiensis at a cost of $13.70 per acre. Bureau personnel treated 400 acres in 1979 with Gypchek, the virus of gypsy moth, and assisted the federal Forest Service with tests of new formulations of Bacillus thuringiensis and Gypchek.

With numbers of gypsy moth increasing, the Bureau assisted municipalities in 1980 providing information from egg mass surveys, and assisting with determining areas to be treated, types of spray equipment to be used, which insecticides were acceptable, and timing of treatments. Eleven communities treated for gypsy moth with carbaryl or Bacillus thuringiensis.

The mandate of the programs of the Bureau, survey, evaluation, and control, changed when research was added in

1971. Faced with the continuation of the spread of the gypsy moth, the U.S. Department of Agriculture developed cooperative research agreements with the Bureau of Insect Pest Control, recognizing that Massachusetts had the longest experience working with gypsy moth and other states could benefit from this expertise.

The cooperative research programs included measuring factors responsible for changes in population numbers, examining the impact of gypsy moth feeding on tree vigor by examining the starch content of roots, determining the presence and benefit of natural control factors (parasites, predators, small mammals, and birds), and examining the relationships between the size and vigor of caterpillars and the number and size of egg masses produced.

Bureau personnel assisted with two federal programs testing alternative methods of gypsy moth control. The first method tested was the release of sterile gypsy moth males to reduce gypsy moth numbers. Female gypsy moths normally mate once, and a female mated by a sterile moth would produce infertile eggs.

Sterilized pupae were supplied by the federal Animal and Plant Health Inspection Service Methods Development Center at the Otis Air National Guard Base on Cape Cod. These pupae were placed in low density gypsy moth populations. The numbers used were to achieve an approximate ratio of ten sterile males to one resident (feral, or non-sterile) male. The 10:1 ratio was to increase the probability that most female moths would mate with a sterile male. Tests with this novel approach were conducted in Massachusetts and other states. The results were less than expected, since the sterilized males were less vigorous and competitive than the resident, feral males in finding and mating with females. After several years

of testing, the program was terminated.

The second program using a novel approach for control was conducted with the Agricultural Research Service of the U.S. Department of Agriculture. The sex pheromone produced by the female gypsy moth had been identified, and synthesized as disparlure. Disparlure, incorporated into tiny plastic 'straws' that effected a slow, sustained release of the pheromone, was applied by air to a low density population of gypsy moth.

The concept tested was that gypsy moth males, faced with a huge number of point sources of disparlure, would be 'confused' and hampered in their search to find and mate with females, a technique named mating disruption. The first test of disparlure was in Erving State Forest where 16,000 acres were treated in 1973 at the rate of 2 grams of disparlure per acre. Untreated plots had a four fold increase in gypsy moth egg masses, whereas the disparlure treated plots had no increase. Four square miles on Mt. Zion were treated in 1974, again demonstrating good results. Mating disruption with disparlure is currently used in low density populations in southern and mid-western states to slow the spread of gypsy moth.

A cooperative agreement with the federal Forest Service in 1979 tested the gypsy moth virus as an insecticide. The virus is produced by culturing, then infecting gypsy moth caterpillars. Dead caterpillars are macerated and the virus particles, embedded in protein capsules called polyhedra, are centrifuged out and frozen. The virus was registered as Gychek by the U.S. Environmental Protection Agency (EPA) for use against gypsy moth. Gypchek is still being produced in limited quantities.

Moths Program, 1981-1990. The greatest outbreak of gypsy moth recorded in Massachusetts began to build in the late

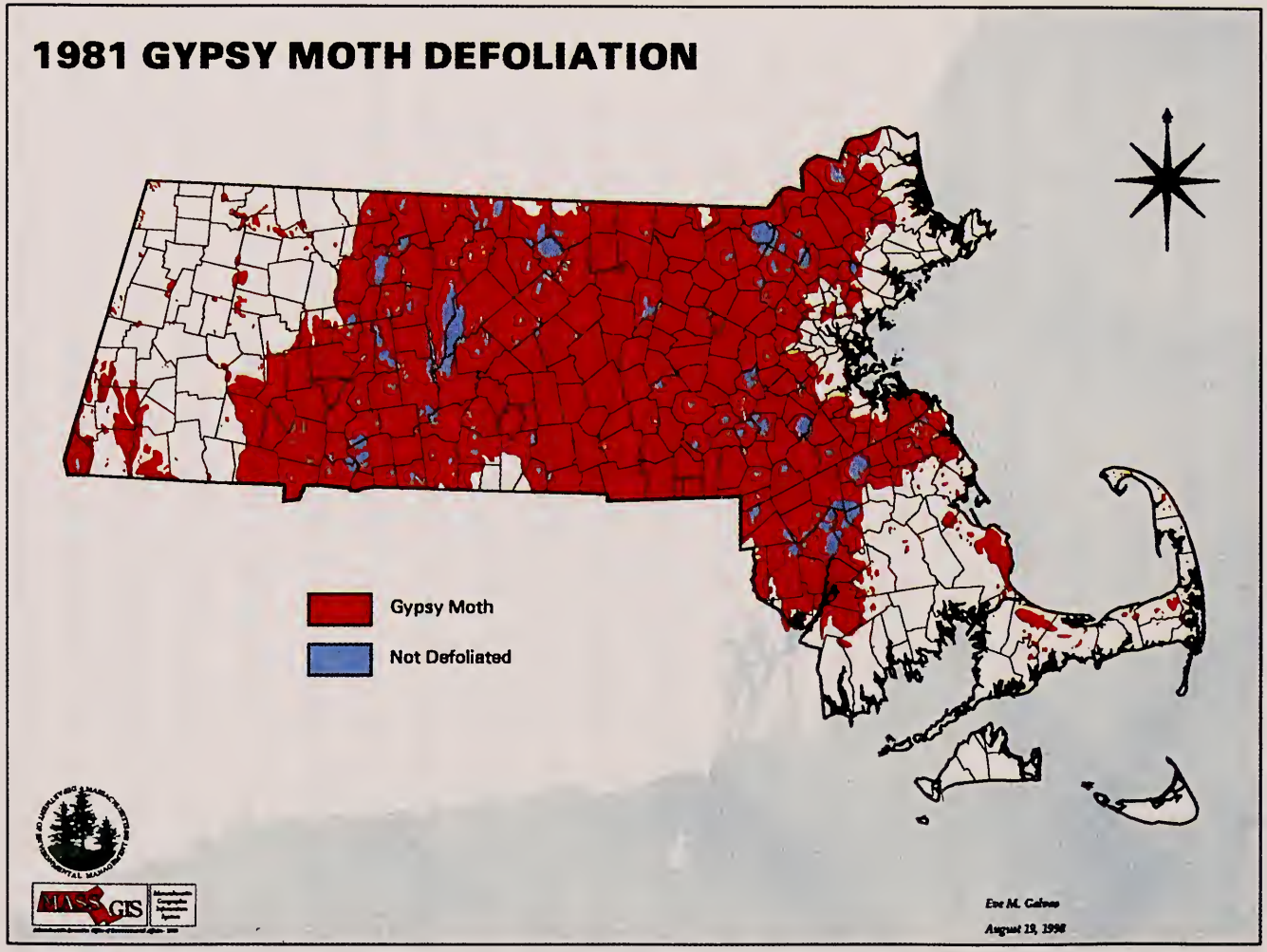


Figure 7. Map of defoliation by gypsy moth in 1981. The more than 2.8 million acres defoliated was the highest recorded in Massachusetts.

1970's. Nearly 910,000 acres were defoliated in 1980, and although there were spots of defoliation in much of the State, defoliation was most severe in Franklin, Bristol, and Norfolk Counties. This was the prelude to the highest amount of defoliation recorded for Massachusetts, 2,826,095 acres in 1981. Little of Massachusetts remained unscathed in this massive outbreak (Figure 7). The following year more than 1.3 million acres were defoliated. Defoliation remained at about 200,000 to 400,000 acres between 1983 to 1986 before dropping in the years following (Appendix 1).

The name of the Bureau was changed from Insect Pest Control to the Bureau of Shade Tree Management and Pest Control in 1981. After several years of drafts and revisions, the environmental impact report on gypsy moth was completed by the Bureau in 1981. Recommendations included the use of suppression techniques that result in the least hazard to human health, wildlife and the environment. Integrated Pest Management (IPM) techniques were advised, utilizing natural control agents such as parasites, predators, Gypchek, and disparlure. The report recommended that the Bureau continue to survey and provide information to aid in decision making regarding control programs at the local level.

Predictions of the size of the outbreak expected in 1981 engendered more interest in municipalities to conduct control programs. As in past years, Bureau personnel provided the information needed by communities, and 116 opted to conduct control programs. Nine communities treated by air and with ground equipment and the remainder treated using ground sprayers. Most programs used carbaryl, with the others treating with Bacillus thuringiensis, malathion, imidan, bidrin, or orthene.

Defoliation levels the following year, 1982, were reduced by more than one half, but still remained high at 1,379,735 acres. In preparation for the season, the Bureau distributed their 1982 policy recommendations to each of the 351 cities and towns in the Commonwealth. The Bureau also sent a survey form to communities to determine how many contemplated control operations to develop a reasonably accurate estimate of costs for possible reimbursement. At the request of the Bureau, the federal Forest Service set aside funds to reimburse cities and towns that conducted aerial spray programs. The State Legislature also appropriated $300,000 to assist cities and towns with the costs of ground spray programs.

One hundred and eight communities conducted control programs in 1982. Bacillus thuringiensis was used in 17 communities, 16 using ground equipment, and one using aerial application. Must communities applied carbaryl, with 19 using aerial applications, and 72 using ground equipment.

As commonly occurs when gypsy moth outbreaks peak, epizootics of the gypsy moth virus kill nearly all caterpillars, bringing an end to the outbreak cycle. The acreage defoliated in 1983 declined to about 218,000 acres, and only nine communities had control programs. Each used ground equipment with carbaryl or Bacillus thuringiensis. Twelve communities treated in 1984, twelve in 1985, and two, Northbridge and Blackstone, in 1986 using the recommended insecticide Bacillus thuringiensis. Although some costs were reimbursed by State and federal funds, the treatments were expensive, and municipalities discontinued spraying programs.

Following the heavy outbreaks of the gypsy moth in the early 1980's, signs of tree mortality began to appear, and the Bureau set up study plots throughout the State to measure tree mortality. The study, completed in 1986, found 17.3% of trees

over 5 inches in diameter had died.

The Department initiated a cooperative agreement in 1984 with Professor Joseph Elkinton of the Department of Entomology, University of Massachusetts, Amherst. Permanent study plots were established throughout Massachusetts. Gypsy moth populations were closely monitored each season to detect changes in numbers and the factors causing the changes. These data are used to predict outbreaks so control measures can be initiated prior to outbreaks occurring. The development of permanent plots to monitor and predict population changes was a new approach for gypsy moth management. As with forest fires, much less energy, money, and personnel are required in early intervention than by having to combat a conflagration (or an outbreak). These plots continue to serve as a primary method to predict population trends of gypsy moth. Other states have adopted this system as a model to develop permanent monitoring plots.

Stan Hood retired in 1987, after 29 years as Bureau Chief, and his retirement was followed the next year by Douglas Trefry, with over 40 years of service, 18 as Assistant Bureau Chief. Stan Hood was replaced by James MacArthur, and Doug Trefry by Ernest DeRosa.

Chapter 8.

Fungus Disease Appears and Current Status of Gypsy and Browntail Moths in Massachusetts

Epizootics of Gypsy Moth Fungus Disease. Gypsy moth populations were decimated on Cape Cod in 1988 by what was thought to be the virus disease. In retrospect, however, the description of the disease symptoms were more characteristic of the fungus disease, *Entomophaga maimaiga*. Cadavers of virus-infected caterpillars are flaccid, hence the name wilt virus, and are normally oriented with the head facing upward. Caterpillars killed by the fungus are not flaccid, and are usually oriented with the head facing downward on trees, as was described for dead caterpillars on Cape Cod. At that time, however, there was no indication that *Entomophaga maimaiga* had established in North America.

Confirmation of the establishment and wide spread occurrence of *E. maimaiga* came in 1989. The epizootics of *E. maimaiga* demonstrated the devastating effects of the pathogen, leaving few surviving caterpillars. In many areas where defoliation was anticipated, the fungus decimated gypsy moth populations before defoliation occurred.

The fungal pathogen was soon discovered in other states and has spread naturally, or was seeded into much of the current range of the gypsy moth. The number of acres defoliated by gypsy moth in North America has declined precipitously, and *E. maimaiga* is generally considered the most significant factor in this decline.

There is no consensus about the origin of *E. maimaiga* in North America. The efforts in Massachusetts early in the century to establish an entomopthoran fungus from Japan, likely *E. maimiaga*, by seeding diseased caterpillars in Eastern Massachusetts might well be the source of spores.

Status of Gypsy and Browntail Moths in Massachusetts. The last control program for the gypsy moth in Massachusetts was in 1992, when 2,270 acres of State park lands and a por-

tion of Boxboro were sprayed with Bacillus thuringiensis. The acreage defoliated by gypsy moth continued to drop from nearly 80,000 to 7000 acres from 1994 to 1996 (Appendix 1), with most of the 1996 defoliation on the South Shore.

Gypsy moth defoliation reached its lowest level in the past 30 years in 1997, with 115 acres defoliated along Rt. 495 in Milford and Lawrence. The low ebb in gypsy moth numbers may be short-lived, however, as data from the permanent motoring plots indicate that the gypsy moth is increasing, and some defoliation is expected in 1998 in southern Worcester County, along the Rhode Island border, in Milford and Lawrence along Rt. 495, and in the Hingham area. Increases in egg masses were also noted on Cape Cod, and at the north end of the Quabbin Reservoir.

Browntail moth rebounded in the Cape Cod National Seashore, defoliating 1185 acres in 1985, mostly beach plum in the Cape Cod National Seashore. Mortality of beach plum was evident in 1997. More than 20 cases of rash caused by browntail caterpillars were reported annually during the outbreak.

The sex pheromone of the browntail moth was recently identified and synthesized. The pheromone was used in traps and resulted in capture of some male browntail moths on Plum Island in 1997. These moths were either from a small, undetected resident population on Plum Island, or blown from the population on the tip of Cape Cod.

The limitation of the browntail moth to the outer tip of Cape Cod, and perhaps, on Plum Island as well, differs from the situation now faced in Maine. The browntail moth, long restricted to islands in Casco Bay, spread back to the coastal regions several years ago, and now can be found along nearly the entire coastal portion of Maine. Insecticides are being used

to contain the spread, reduce the severity of the outbreak, and lessen the exposure of humans to the consequences of the toxic hairs of caterpillars.

Focus of the National Gypsy Moth Program. The gypsy moth is now in 17 states with the western and southern margins extending from Wisconsin to North Carolina. The spread to other states continues to be a concern. There is a state and federal program named Slow The Spread (STS) along the current border of the gypsy moth infestation in North Carolina, Virginia, West Virginia, and Michigan. The STS program utilizes an intensive monitoring program in a transition zone beyond the current infested areas. Where populations of gypsy moth are found in the transition zone they are closely monitored; if necessary, intervention programs are initiated. Plans are underway to include the other border states in the STS program.

Chapter 9.

Biological Control of Gypsy and Browntail Moths.

Origin of program. Entomologists had recognized that the severity of outbreaks of introduced pests was due, in part, to the absence of natural control agents that help regulate populations in their native lands. With the exception of the gypsy moth virus, the gypsy and browntail moths arrived without their native biological control agents. Given the spectacular success of importing a ladybird beetle (*Vedalia*) from Australia to attack an introduced scale insect killing citrus trees in California, entomologists invited to Massachusetts in 1893 to view the gypsy moth program suggested importing natural enemies of the gypsy moth from Europe.

Foreign exploration for parasites and predators of the gypsy moth and browntail moth were initiated in a joint program with Massachusetts and the federal Bureau of Entomology in 1905. That year, the Massachusetts Legislature appropriated $30,000 to be expended over three years for importation of parasites and predators. Dr. L. O. Howard, Chief of the Bureau of Entomology was in charge of the federal, and A. H. Kirkland, the Massachusetts efforts. A federal laboratory was constructed in Melrose Highlands. F. H. Mosher, a State employee, was assigned to the laboratory to work with federal entomologists.

Shipments from Europe, packed in ice and sent by boat, were transported to the laboratory at Melrose Highlands. Parasites and predators were cultured to obtain sufficient numbers for release. As the program developed, more efforts were made to insure that species imported would not become pests and were carefully screened to determine that they carried none of their own parasites or diseases. State support for this work totaled nearly $75,000 by 1909. In December, 1911, after six years of sharing efforts, Massachusetts turned over the pro-

gram of importation and establishment of natural control agents to the U.S. Department of Agriculture. Some State employees were transferred to the federal payroll.

The efforts to seek natural control agents for gypsy and browntail moths was the most ambitious program of its type ever attempted. The program was interrupted during both World Wars. The federal program still exists, but for a wider range of introduced pests, including plants, and continues to have strong participation from states. Massachusetts continues to cooperate in the release and evaluation of natural control agents for the gypsy moth and other introduced pests in the Commonwealth.

Pathogens. The first foreign exploration conducted by Massachusetts was a private venture. Dr. G. P. Clinton of Harvard was funded in 1909 through a friend of Harvard for exploration in Japan for pathogens of the gypsy and browntail moths. He returned with two fungal pathogens in the genus *Entomopthora*, one each attacking the gypsy moth and browntail moth. The task of culturing the fungi and distribution of the pathogens in Massachusetts woodlands was placed under the direction of Dr. Roland Thaxter of Harvard, who spent summers on the program.

The fungus disease of the browntail moth cultured readily, and when seeded in browntail moth infestations, quickly spread, infecting and killing millions of caterpillars. The fungus disease of the gypsy moth, however, was not as readily cultured, and field results were disappointing. Mr. R. H. Colley supervised Dr. Thaxter's field research, and noted:

> **"That the gypsy fungus will prove as destructive as the browntail fungus, seems, in view of the negative results so far obtained, very doubtful, but there is a possibility that it may get started from some of its nu-**

merous resting spores which must be in the field in localities where the fungus was planted, and which case its effectiveness might prove to be greater than our experiments would indicate."

These overlooked comments on the value of this fungal disease could well be prescient. *Entomophaga maimaiga*, found on Cape Cod in 1988, is now the primary factor in the current spectacular reduction of outbreaks in much of the range of gypsy moth in North America. Although the original source has not yet been determined, the importation of *Entomopthora* in 1909 by Dr. Clinton may have been the source of spores.

Parasites. To date, over 30 species of parasites have been released against gypsy and browntail moth. Of these, nine are considered successful introductions (Appendix 2) since they maintain themselves in sufficient numbers to exert some level of control.

One of the earliest introductions, and the most spectacular in establishment and spread, was the parasitic fly *Compsilura concinnata*. The spread was one of the most rapid ever recorded for a parasite. Equally impressive is the large number of different hosts parasitized. Caterpillars of over 200 species of butterflies and moths are attacked, not all of them pest species. *C. concinnata* has several generations a year, but only one generation develops in gypsy or browntail moth caterpillars.

Two introduced parasitic wasps attack eggs of the gypsy moth; one, *Ooencyrtus kuvanae*, established and spread rapidly. The second species, *Anastatus disparis,* also established but its distribution is limited since female wasps are wingless and spread is slow. During the 1970's and 1980's, Douglas Trefry collected *A. disparis* transported them to Cape Cod and other areas of Massachusetts, attempting to establish the

parasite in new areas.

Cotesia melanoscela, a parasitic wasp that attacks caterpillars, was another of the early introductions that showed much promise. Females attack small caterpillars; when the first brood completes development, the second generation of wasps attack mid-sized caterpillars. Early studies showed that *Cotesia melanoscela* was itself attacked by number of species of native parasites (hyperparasites), greatly reducing its effectiveness.

Predators. One of the first successful introductions of natural control agents was the iridescent, predaceous beetle, *Calosoma sycophanta*. (Figure 8). The beetle, about an inch long, and the larvae, about 1 1/2 inches when fully grown, are voracious feeders on gypsy moth caterpillars and pupae. The predator colonized rapidly, but did not move northward beyond Massachusetts. Fewer predators than parasites were introduced, and *C. sycophanta* was the sole predator to establish.

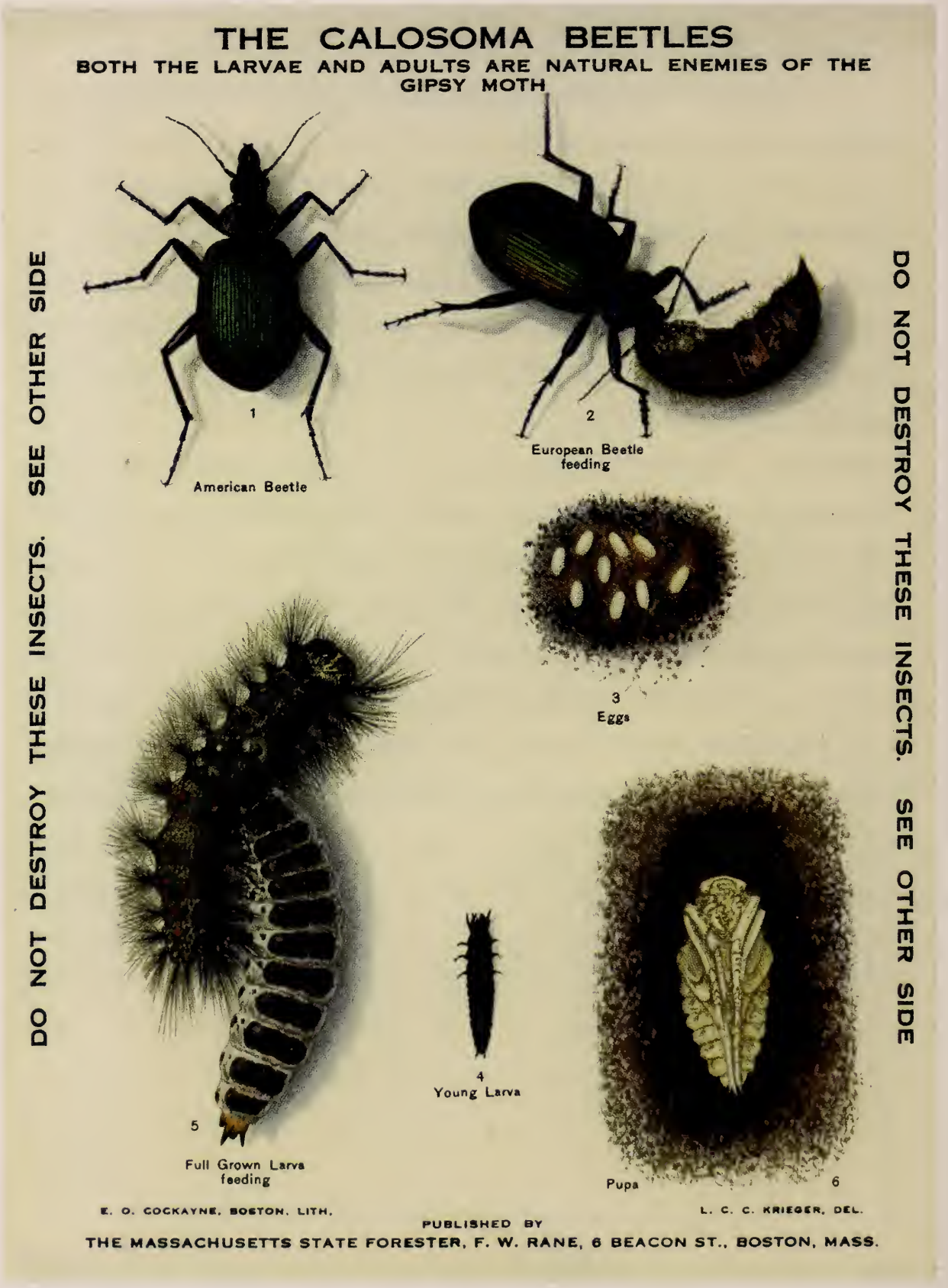


Figure 8. *Calasoma sycophanta*, a beetle introduced for biological control of gypsy moth. Both adults and larvae are voracious feeders on gypsy moth caterpillars and pupae. From a postcard produced about 1912 by the State Forester of Massachusetts.

Birds. Charles H. Fernald and Edward H. Forbush were among the first enlisted by Massachusetts to work on the gypsy moth. E. H. Forbush was interested in birds, and later became the State Ornithologist. Their book, The Gypsy Moth, published in 1896, is the definitive treatise on the early history of the gypsy moth in Massachusetts. In the book, Forbush listed 28 species of birds feeding on various stages of the gypsy moth. Most fed on caterpillars, but one, the chickadee, fed on all stages—eggs, caterpillars, pupae, and moths. E. F. Mosher, another astute observer of birds, considered that as many species of birds that fed on gypsy moth also fed on browntail moth.

E. H. Forbush later responded to concerns that arsenate of lead was killing birds. He found some mortality occurred when birds drank from puddles containing the insecticide. He noted that defoliation exposed the fledglings, and the high rate of mortality in exposed fledglings had a greater impact on bird populations than arsenate of lead.

Predation by birds (and by small mammals such as mice) has little impact during outbreaks of gypsy moth. With huge numbers of available caterpillars, birds become satiated and the percentage of prey consumed is negligible.

Chapter 10.
Oak Leaf Complex.

The 1970's and 1980's were periods of extensive outbreaks by a complex of moths attacking oaks. Three insects were dominant, the oak leaf tier, the oak leaf roller, and the oak leaf skeletonizer.

Oak Leaf Tier, *Argyrotoza semipurpurana*, occurs from southern Canada throughout the eastern part of the United States. Red oak is the preferred host. There is one generation per year; moths emerge in June and early July and lay eggs that hatch the following spring. Caterpillars feed first on buds, then on leaves, silking several leaves together. Caterpillars reach about one-half inch in length, and are dirty-white to green.

The oak leaf tier defoliated 30,000 acres in eastern Franklin County in 1976, and the outbreak continued and spread to red oak forests in Norfolk, Hampden and Berkshire Counties. The acres defoliated were: 1977, 100,665; 1978, 101,545; 1979, 103,670; and 1980, 17,660. The outbreak ended in 1980.

The complex of oak leaf tier and oak leaf roller defoliated 69,363 acres in Bristol and Norfolk Counties in 1984. The situation was more complex in Bristol and Norfolk Counties in 1985 when 355,125 acres were defoliated by a combination of the oak leaf tier, oak leaf roller and gypsy moth. Of this total, the oak leaf tier-leaf roller complex accounted for over 50% of the defoliation on nearly 182,000 acres. The combination of oak leaf roller, oak leaf tier, fall cankerworm, and gypsy moth defoliated 108,653 acres in 1986. This outbreak continued into 1988, defoliating nearly 362,000 acres, primarily in Barnstable, Bristol, and Norfolk Counties, with lighter amounts of defoliation on 200,035 acres Bristol and Norfolk Counties. The outbreak subsided, and there was no noticeable defoliation in 1990.

There also was a concurrent outbreak in eastern Franklin

County, with 3,360 acres defoliated in 1985, 13,224 acres in 1986, and 20,096 acres in 1987. The heaviest infestation was in Warwick, where for the first time the oak leaf tier was found feeding on white oaks. The insect defoliated approximately 11,000 acres in Warwick, Wendell, and Sunderland in 1988, with a small outbreak also in Worcester County. These outbreaks abated, with no noticeable defoliation in 1990. Oak leaf tier populations continue to be monitored using pheromone traps.

Experiments in 1986 and 1987 tested diflubenzuron (Dimilin) on three, two acre blocks. Diflubenzuron, a slow acting insecticide that disrupts molting of caterpillars, provided excellent protection of foliage. A project to spray 3,000 acres of Warwick State Forest with diflubenzuron was canceled because of concerns raised by individuals and environmental groups. There were two small tests in 1989 using Bacillus thuringiensis and diflubenzuron.

The oak leaf tier was previously unknown as a forest defoliator in Massachusetts, as were its' impacts on red oak. Forty-four study plots were establish in the spring of 1987 to monitor the condition of the red oaks in defoliated sites and in sites that had not experienced defoliation. Among factors measured were tree growth, root starch content, and condition of the tree crown. Dead oaks began to appear in 1979, particularly in Wendell State Forest. By 1983, 17% of the red oaks had died, mostly understory trees. The estimated loss in sawlog class red oak was $276 per acre due to the combination of loss of tree growth and mortality. By the end of the study in 1985, the average mortality in red oak stands in eastern Franklin County was 28.7% of trees over five inches in diameter.

Oak Leaf Roller, *Archips semiferanus*, closely related to the oak leaf tier, has much the same appearance and habits. It occurs in eastern and central North America, with widespread and periodic outbreaks recorded since the 1960's. Preferred hosts are oaks. Caterpillars curl leaves with silk, and remain in the rolled leaves.

Oak leaf roller caused spotty areas of defoliation in 1970 and 1971 in Mount Washington and Plymouth. The next outbreak was in 1986-1989 when the oak leaf tier-oak leaf roller complex defoliated more than 100,000 acres yearly in Bristol and Norfolk Counties (see above).

Oak Leaf Skeletonizer, *Bucculatirix ainsliella*, has two generations a year. The small moths appear in April and May, with a second generation in July and August. The second generation produces the greatest amount of defoliation. The yellowish-green caterpillars enter and mine leaves. Older caterpillars leave the mines and feed on the underside of leaves, resulting in foliage that is nearly transparent. Full grown caterpillars are about one-third of an inch in length. Caterpillars spin down from leaves when ready to pupate, and where numbers are high they can be a nuisance. Also, they form white, silken cocoons on nearly any object, including automobiles, lawn furniture, and window screens.

The oak leaf skeletonizer reached outbreak proportions in 1969 in eastern Massachusetts, particularly in Middlesex and Essex Counties. Oaks in most of Massachusetts were being attacked in 1970, with the highest infestations in eastern Massachusetts. The outbreak showed signs of declining in 1971 and it ended in 1972.

The oak leaf skeletonizer began to increase in 1985 in the southern portion of the Connecticut River Valley, eastward to Worcester County, defoliating 66,000 acres. The second

generation spread through much of Massachusetts. The following year, large numbers occurred in Essex, Bristol, and Norfolk Counties, with patchy infestations in Middlesex County. The outbreak ended in 1989 with a few infestations in Essex and Middlesex Counties.

Chapter 11.

Other Pests of Deciduous Trees

Beech Scale-*Nectria*. The beech scale insect, *Cryptococcus fagi*, and the bark-killing fungus of beech, *Nectria ditissima,* were both introduced into North America from Europe. The scale insect was first noted in the Arnold Arboretum in Boston in 1929. *Nectria* was first found in Nova Scotia in 1920, and by 1932 had spread southward to eastern Massachusetts. The scale feeds by inserting its sharp mouthparts into the bark, and the fungus infects the bark through the feeding wound of the scale.

The scale covers itself with a waxy, white secretion; when densities are high, infested trees are readily visible. The fungus is identified by bright, red fruiting bodies containing spores. Infection of large areas of the trunk girdles and kills the tree. When smaller areas of a trunk are attacked, callus tissue forms, causing roughening of the bark.

Most of the beech stands are in northern Worcester County, through Franklin County, the eastern slopes of the Berkshires in Hampden and Hampshire Counties, and Berkshire County. In 1967, beech scale or *Nectria* was found in all areas where stands of beech occurred. Some areas contained the scale insect, but not the disease, but many contained both the scale and the *Nectria* and dying or dead beech trees. By 1982, beech scale-*Nectria* ranked second behind Dutch elm disease in number of trees killed. Beech, however, is not considered a valuable timber resource, and the scale is difficult to control. No control measures have been conducted in natural stands of beech.

Eastern Tent Caterpillar, *Malacosoma americanum,* commonly found in the eastern North America, is easily distinguished by the white tent of silk. The gregarious caterpillars construct tents in the spring in the crotch of a branch. Preferred hosts are fruit trees and wild cherries. It is a pest on

ornamental crabapple and cherry, and nests are most noticed along roadsides on wild cherry.

Outbreaks of eastern tent caterpillar occurred in Massachusetts in 1912-14, and 1924. Eastern tent caterpillar outbreaks were common and widespread from 1934 until 1944. The Legislature added control of tent caterpillar as a responsibility of the Department of Conservation in 1937. The 1939 Works Progress Administration (WPA) program sprayed with arsenate of lead and cut and destroyed more than 1.1 million webs. Bureau personnel conducted educational programs. School children were encouraged to search and destroy clusters of eggs during the early years of World War II.

Outbreaks of eastern tent caterpillar again peaked throughout the State in 1978. Berkshire and Middlesex Counties experienced an outbreak in 1988-1990, as did Worcester and Middlesex Counties and the outer portion of Cape Cod in 1995 and 1996.

Saddled Prominent, *Heterocampa guttivitta*, occurs in eastern North America, and preferred hosts include beech, sugar maple, and birch. In outbreaks, saddled prominent also feeds on other species of deciduous trees, including oaks and poplars. Moths appear in late May and early June. Caterpillars are about one and one fourth inch when fully grown, and green with purple, gold, and brown markings on the back. The host preferences for northern hardwoods restrict the saddled prominent to western portions of Massachusetts.

Outbreaks of saddled prominent occurred in Berkshire County in 1931, and in 1955-1957 in the Williamstown area bordering an outbreak in New York State. The outbreak in Williamstown was treated in 1957. The insect began to increase in Savoy in 1962 and defoliated 400 acres of the Savoy State Forest the following year.

The largest outbreak of saddled prominent started in Berkshire County in 1967 and continued until 1973. Scattered defoliation also occurred in Hampden, Hampshire, and Franklin Counties. The defoliation by year was: 1967, 5,500; 1968, (with red-humped oakworm) 32,000; 1969, 92,000; 1970, 105,000; 1971, 23,800; 1973, 2,503 acres.

Saddled prominent appeared in Berkshire County in 1980-1982, and in Hampshire and Franklin Counties in 1982, but populations declined before there was widespread defoliation. The insect defoliated 5,000 acres in Berkshire County in 1985, but the outbreak ended with no defoliation reported the following year. There were spotty areas of defoliation in northern Berkshire County in 1997.

Fall Webworm, *Hyphantia cunea,* is found throughout Eastern Canada and the United States. Caterpillars feed on more than 100 species of deciduous forest and shade trees and, on occasion, defoliate large areas. Moths appear in May and June to mate and lay eggs. The communal caterpillars produce large, silken webs on the branch terminals in mid-summer. Fall webworm is not considered a threat to forests because feeding occurs late in the season, usually on understory trees. Webs along roadways and on shade trees and ornamentals are unsightly, and prompt many inquires.

Fall webworms were most abundant in the years 1931, 1934, 1942, 1960, 1973-1977, 1990, and 1994-1996. Scattered outbreaks appeared throughout the State, but often were heaviest on Cape Cod. The Provincetown area was sprayed in 1960.

Spring and Fall Cankerworms. Fall cankerworm, *Alsophila pometaria,* and spring cankerworm, *Paleacrita vernata*, are common to eastern North America. Both share similar preferences for a number of species of hardwoods. Common names

for caterpillars are measuring worms and inch worms. Both species have periodic outbreaks, sometimes concurrently.

Adults of the fall cankerworm emerge in November or December from cocoons in the soil. The wingless female moths crawl up trees, attract males, mate, and lay eggs on twigs. Fully grown caterpillars are about an inch long, light to brownish, with a dark stripe down the back. Female moths of the spring cankerworm, also wingless, emerge in early spring to lay eggs. Caterpillars vary from reddish to yellowish brown to black with a yellow stripe along the side.

Fall cankerworm defoliated hardwoods in eight towns in Berkshire County in 1936. A heavy infestation on Martha's Vineyard was sprayed in 1960. Spring and fall canker worm populations began to build in 1961 in Quincy, Newton, Holyoke, and Pittsfield. Defoliation in parts of western Massachusetts in 1962 attributed to gypsy moth was caused, in part, by cankerworms. Cankerworms defoliated 16,500 acres in 1962 and 18,000 acres in 1963 in areas of Braintree, Canton, Holbrook, Milton, Quincy, Randolph, Weymouth and Cohasset. In 1963, 10,350 acres required treatment, including 3,900 in Braintree and 6,000 in Weymouth. Cankerworms defoliated this general area, along with parts of Norwell and Marshfield, in 1995-1997.

Fall cankerworm defoliated 4000 acres on Nantucket in 1966, nearly 8,500 acres in Braintree and Weymouth in 1986 and 2,000 acres in Scituate, Falmouth, and Nantucket in 1989.

Pear Thrips, *Taeniothrips inconsequens*, spread eastward from California, where it was introduced from Europe in 1904. Sugar maples are one of the favored hosts. Pear thrips feed on buds and young leaves, causing leaves to become stippled yellow-green to brown.

Pear thrips were first noted in Massachusetts in the mid-

1980's. The insect defoliated more than 108,000 acres of sugar maples in 1987 and 139,000 acres in 1988. Although pear thrips numbers were still rather high in 1990, there was little damage and no outbreaks have occurred since. Bureau personnel continue to monitor pear thrips using yellow sticky panels that attract and trap adults.

During the outbreak of pear thrips, trees were severely stressed and the quality and quantity of maple syrup declined. The Bureau also participated in the North American Maple Project, initiated in 1987. The condition of maple trees in managed and unmanaged stands was assessed. The 1996 data showed 93% of the sugar maple trees in healthy condition with little difference between managed and unmanaged stands, indicating sugar maples recovered from the effects of defoliation in the mid-1980's.

Satin Moth, *Stilpnotia salicis*, is native to Europe and a defoliator of species of poplars and willows. It was first found on the border of Malden and Medford in 1920 (and, in the same year, in British Columbia, Canada). Thus, satin moth became the third tussock moth (the gypsy moth and browntail moth the others) to gain entry into North America near Boston.

The satin moth derives its name from the satiny-white moths that appear in late June and early July. Females lay masses of 100-400 eggs. Caterpillars feed on the underside of leaves, then spend winter on tree trunks. Caterpillars resume feeding in springtime and reach just over an inch long, with a white spot on the top of each segment. The satin moth periodically defoliates ornamental poplars and cottonwoods; infrequent outbreaks occur in natural stands of poplars.

A survey conducted when the satin moth was first discovered found the insect in 60 towns in Massachusetts as well as in southern New Hampshire. As with most newly-invading

species, it was at first a troublesome pest, spreading rapidly and completely stripping trees in some towns. Early records of damage in eastern Massachusetts include 1924, 1928, 1931, 1936, 1937, and 1941, primarily on introduced species of ornamental poplars. There was some defoliation in the central part of the Massachusetts in 1989, and 500 acres of natural poplar stands were defoliated in Berkshire County in 1991 and 1992.

Elm Leaf Beetle, *Xanthogaleruca lutelola*, was introduced into Maryland in 1830 (likely from Europe) and spread rapidly. It became a pest in Massachusetts in the 1890's. The yellowish to green beetles, about one-third inch long, spend the winter in dark dry areas, often in attics. The beetles emerge to lay eggs about the time elm buds swell. Beetles and larvae feed on the undersides of foliage, skeletonizing leaves.

Widespread defoliation of elms occurred in Massachusetts in 1901, 1908, 1914, 1931-1938, and 1960. Early efforts of control were frequently combined with treatments against gypsy moth, using arsenate of lead. Later, DDT was used; in 1961, the beetle showed some resistance to this insecticide. A parasitic fly from France, *Anachaetopsis nitidula*, was released in Woburn in 1934, but there is no record of establishment. With the demise of the American elm due to Dutch elm disease, the European elm leaf beetle is now an incidental pest of other species of elms.

Asian Long-Horned Beetle, *Anoplophora glabripennis*, native to China, appeared in Brooklyn and Amityville, Long Island, New York in 1996. Whether the beetle spread from these locations is not yet known. Adult beetles are large, black, with prominent white spots on the back and white banding on the long antennae. Preferred hosts include species of maple, poplar, and willows, although other trees species are also attacked.

Larvae bore through the wood, and take two years to mature. Where numbers of larvae are large, trees are killed.

The U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), along with municipal and state agencies, are attempting to eradicate the beetle in Brooklyn and Long Island by cutting and chipping all infested trees. The insect is being studied in the quarantine facility of the APHIS Plant Protection Center at Otis Air National Guard Base on Cape Cod. Personnel of the State Forest Health Program are assisting these studies of feeding preferences and development of Asian long-horned beetles by providing samples of more than 20 species of native trees.

Chapter 12.
Incidental Pests of Deciduous Trees

Buck Moth, *Hemileucana maia*, occurs in much of the eastern half of the Unites States, and feeds on oaks. Fully-grown caterpillars are about 2 1/2 inches long, brown-black, and covered with bumps containing irritating hairs. A large population of buck moth was found in the Ashburnham area in 1983.
Cherry Scallop Shell Moth, *Calocalpe undulata*, occurs in much of eastern North America feeding on wild cherries. Caterpillars grow to about three-fourths of an inch long, and construct silken nests on the terminals of branches. Infestations of cherry scallop shell moth occurred in Great Barrington, Egremont, and Otis in 1972 and in Worcester County in 1991.
Cottony Maple Scale, *Pulvarinaria innumerabilis*, occurs throughout much of North America and favors maple, but a wide variety of deciduous trees are also used as hosts. Nymphs of this scale insect hatch in May and June, suck sap from leaf veins, and cover themselves with a cottony secretion. Heavy feeding reduces tree vigor and makes them more susceptible to attacks by other insects. Honeydew, the excretion of the scale, drips from infested leaves and is often a nuisance. Honeydew also serves as a medium for the growth of sooty mold, detracting from the appearance of shade and ornamental trees. Cottony maple scale is a pest of ornamental and shade trees, and outbreaks of rarely last more than a year. The scale was abundant in 1931.
Gouty Oak Gall, *Callirhytis punctata*, common to eastern North America, attacks many oaks, including scarlet, pin, and black oak. The small wasp lays eggs in spring, producing small, gout-like galls. Where infestations are heavy, damage and tree death can occur. Although the gouty oak gall is not normally a problem, numbers were high in 1995 in Carver, Plymouth, Halifax, Taunton, and Lakeville. The insect killed red oak twigs on 28 acres in Plymouth in 1997.

Green-Striped Mapleworm, *Anisota rubicunda,* is found in eastern North America, with outbreaks more common in the South. Preferred hosts are maples, but caterpillars will also feed on oaks. The pale caterpillars grow to over an inch long, and have a red head, two horns on the second body segment, and seven dark green to black lines running along the body. Numbers of green-striped mapleworm were high in 1972 in Pittsfield, Otis, Monterey, Savoy, and Great Barrington.

Leopard Moth, *Zeuzera pyrina*, an introduced insect, occurs in the Northeast. It apparently was a problem in Massachusetts in 1910 and several years thereafter, but there is little information on this infestation. Caterpillars bore into the twigs, branches, or trunks of a number of species of deciduous trees and take two years to develop. Damaged twigs and branches break and saplings are killed in heavy infestations.

Linden Looper, *Erranis tiliaria*, feeds on a variety of hardwoods, with species of maples oaks, and birches among favored hosts. On occasion, outbreaks occur, with one in Massachusetts in 1963. More than 109,000 acres were treated with DDT in Berkshire, Hampden, Hamden, and Franklin Counties for a combined outbreak of linden looper and gypsy moth.

Maple Petiole Borer, *Nepticula sericopeza*, an introduced insect from Europe, attacks Norway maples. Caterpillars mine into leaf petioles and cause premature leaf-drop. Damage occurred in central and southern parts of Worcester County in 1995.

Oriental Moth, or oriental hag moth, *Cnidocampa flavescens*, was first found in North America in Dorchester and Roxbury in 1906. Oriental moth caterpillars feed on and can cause defoliation of a number of species of deciduous trees, including Norway and sycamore maples, fruit trees, and oaks. Fully

grown caterpillars are nearly an inch long, with yellow, blue, purple, and green markings. They also have spines and hairs that cause a severe rash.

Localized outbreaks of oriental moth appeared in Roxbury and Dorchester in 1917, the Boston area in 1928-1931, and Salem, Chelsea, Winthrop, Revere, and Boston in 1938-1941. A parasitic fly, *Chaetexorista javana*, imported from Japan in 1929 and 1930, showed good success in attacking caterpillars. The oriental moth is still confined to the Boston area with no outbreaks recorded since 1941.

Periodical Cicada, *Magicicada septendecim*, is commonly called the 17 year locust, although it is not a locust. One of the oddities of the insect world, the nymphs require 17 years to develop, sucking the sap from roots of a wide range of deciduous trees. Localized broods of periodical cicada are common to areas in the eastern portion of the United States.

Adults emerge simultaneously on an evening in May, usually in large numbers. Adults are more often heard than seen, as their chorus creates a constant din during the day. Females lay eggs in twigs with a saw-like ovipositor. Nymphs hatch, drop to the ground, and burrow to roots to feed. Although root-feeding of nymphs may weaken trees, the primary damage is caused by egg laying females. Branches in which eggs are deposited often break and damage can be severe on small trees and ornamentals. The 1991 brood of periodical cicada damaged twigs on 15,000 acres on Cape Cod.

Red-Humped Oakworm, *Symmerista canicosta*, occurs throughout southeastern Canada and the northeastern United States feeding on oaks as well as on sugar maple, birch, and beech. Larvae reach about an inch, and are yellowish, with dark lines and an orange-red hump at the rear. Outbreaks are not common, but red-humped oakworm, along with saddled

prominent, defoliated 32,000 acres in Berkshire County in 1968.

San Jose Scale, *Quadraspidiotus pernicious*, is native to Asia and was first discovered in California in 1870 and rapidly spread eastward. It established in 52 localities in Massachusetts by 1902, mostly as a pest of orchard trees. Where left unchecked, the San Jose scale killed trees, and the Legislature gave the State Nursery Inspector the authority in 1907 to remove infested trees on private lands where owners refused to take action. The scale is readily controlled in orchards but is an occasional pest on a number of species of ornamentals.

Chapter 13.
Insects Attacking Conifers

Pine Looper, *Lambdina athasaria pellucidaria,* occurs in several Atlantic coastal states and large scale outbreaks can occur on pines. Moths lay eggs in May and June. Caterpillars are light yellow with black markings, and when fully grown are slightly longer than one inch.

Pine looper is most prevalent in Massachusetts on Cape Cod and Plymouth County, feeding on pitch pine. The pine looper is a persistent problem, with outbreaks about every 10 years, 1913, 1922, 1932-1933, 1944-1945, 1971-1975, 1980-1981, and 1994. Pine looper defoliated 34,565 acres in Plymouth County and 8,175 acres in Barnstable County in 1973, surpassing the amount of defoliation by all other insects that year. Portions of upper Cape towns of Bourne, Sandwich, and Mashpee were treated in 1974 using carbaryl applied by helicopter. An outbreak in 1994 defoliated 2500 acres in Plymouth and Barnstable Counties.

Hemlock Loopers. Two species of loopers attack hemlock. *Lambdina athasaria athasaria* occurs in several eastern states. The life history and appearance closely resemble the related pine looper. The Legislature added hemlock looper to the responsibilities of the Department of Natural Resources in 1955 and provided $100,000 to treat 203,000 acres with DDT on Cape Cod. Hemlock looper numbers increased in the Fall River Watershed in 1971 and defoliated 600 acres in the Lakeville-Freetown and Hanover-Pembroke areas in 1972. The outbreak lasted until 1975, killing some mature and over-mature hemlock.

An outbreak of hemlock looper occurred in Essex County defoliating nearly 1,000 acres in 1973 and 2,765 acres in 1974. Most defoliation occurred in Essex, with scattered amounts in Rockport, Gloucester, Manchester, Beverly, and Wenham. The outbreak subsided in 1975, but many mature

hemlocks were lost.

A second hemlock looper, *Lambdina fiscellaria*, is native to Eastern North America. The preferred hosts are balsam fir, white spruce, and hemlock, but during outbreaks, a wide variety of conifer and deciduous trees are defoliated. Adults appear in late summer and early fall, and the insect overwinters in the egg stage. The grayish-green caterpillars reach just over an inch in length when fully grown.

The first record of damage in Massachusetts by this looper was defoliation of 1,633 acres in southern Berkshire County in 1994. The insect defoliated 2,783 acres in Tolland State Forest in 1995. Eight hundred acres of this outbreak were treated with Bacillus thuringiensis with excellent results. There was no noticeable damage in 1996. Populations continue to be monitored, using pheromone traps and egg surveys.

Hemlock Woolly Adelgid, *Adelges tsugae,* is yet another introduced insect (likely from Asia) that is threatening a Massachusetts tree, eastern hemlock. The adelgid is a tiny aphid covered with white 'wool.' Adults and nymphs attack portions of trees where their needle-like mouth parts can penetrate to the cambium to suck out fluids. The insect has several generations a year, and can reach sufficient numbers to kill trees.

The hemlock woolly adelgid first appeared on hemlocks in Springfield in 1989. The insect was found in Waltham in 1990, and continues to spread rapidly (Figure 9). Hemlock woolly adelgid is contributing to tree mortality in trees stressed by factors such as drought. As the adelgid populations increase, more tree mortality is expected.

The State Forest Health Program is cooperating in a study of winter hardiness with the federal Forest Service, Vermont Division of Forests and Parks, and the University of Ver-

mont. Adelgids collected on Mount Tom State Reservation are exposed to low temperatures in a quarantine facility at the University of Vermont. Data collected thus far suggest low winter temperatures will not deter the spread northward.

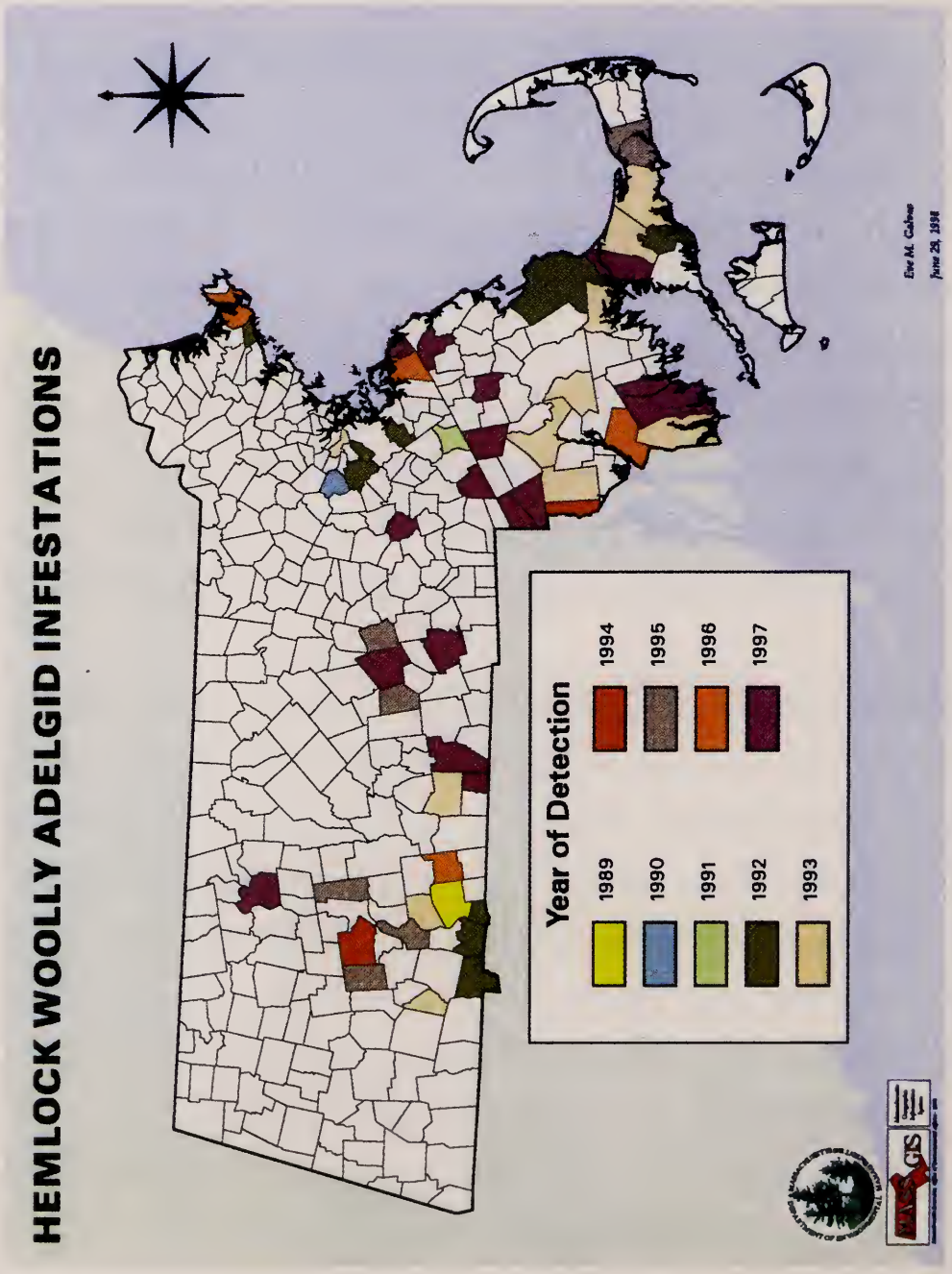


Figure 9. Rapid spread of hemlock woolly adelgid since first found in Springfield, Massachusetts in 1989.

Nantucket Pine Tip Moth, *Rhyacionia frustrana*, common to the eastern United States, attacks most species of pines. Nantucket pine tip moths retard growth of young tree growth, malforming stems, and in some cases, killing pines. Moths appear in early spring and caterpillars mine needles, then feed on buds and mine shoots. There are two generations per year in Massachusetts. The insect is most prevalent in Dukes, Barnstable, and Plymouth Counties.

The first recorded severe outbreak in 1968-1971 on Cape Cod and Plymouth County resulted in the death of thousands of pitch pines. The insect defoliated 500-1000 acres in Scituate and was numerous in Barnstable County in 1976. Numbers of Nantucket pine tip moth increased again in Barnstable and Plymouth Counties in 1980. Over 8000 acres of pitch pine were damaged in Barnstable in 1994. The tip moth, in concert with salt spray damage, drought, and the effects of pine looper infestations, damaged about 3,100 acres of pitch pine on the outer portion of Cape Cod in 1995.

White Pine Weevil, *Pissodes strobi*, occurs throughout the range of its most common host, eastern white pine, and attacks a range of pine and spruce species. The adult weevils, about one-third of an inch long, emerge in spring and feed on the terminal shoots. Eggs are laid in shoots and grubs feed on the inner bark. The killing of terminal shoots deforms trees, decreasing their value.

The recommended control of white pine weevil in 1915 was cutting and burning infested terminals. For larger trees, or in natural stands of white pine, this practice was not practical. A cooperative study was initiated with Harvard Forest at Petersham in 1920 to learn more of the habits of the weevil. A common management practice now used is the planting of white pine under hardwoods. Since the weevil prefers sunny,

open localities, the protective cover allows pines to reach a height where they are less susceptible to weevil attack.

Larch Sawfly, *Pristiphora erichsonii*, likely an introduced species, was first found in Boston in 1880 and spread throughout Canada and most of the northern tier of the United States. The insect feeds on larches; in Massachusetts, the host is tamarack. Adults appear from mid-May to August. Larvae are gregarious, and feed on needles of older twigs. There are many records of outbreaks in North America, some lasting for many years before trees are killed. Where larches are used for timber and pulp wood, losses have been severe.

Larch sawfly defoliated 8-10 acres in Ware in 1968 and 1969, and 150 acres in 1978. The insect defoliated 110 acres in Lancaster in 1979 and 480 acres in Middlesex County in 1980. Larch sawfly numbers increased in Barre in 1992 and defoliated 25 acres in 1993 and 1994.

Pine Needle Miner, *Exoteleia pinifoliella*, occurs in eastern North America and may undergo two generations per year. Preferred hosts are pines, and in Massachusetts, pitch pine is particularly susceptible. Small caterpillars mine new needles, and older caterpillars mine both new and old needles. Outbreaks of the pine needle miner in Plymouth County resulted in defoliation on 27,400 acres in 1980 and 14,025 acres in 1981.

Chapter 14.
Incidental Pests of Conifers

Arborvitae Leaf Miner, *Argyresthia thuiella*, is found in eastern Canada and throughout many of the eastern and mid-Atlantic states westward to Missouri. Moths lay eggs in spring on arborvitae; caterpillars are small, and mine leaves. Damage is most serious in ornamentals and nursery plantings, but outbreaks do occur in forest stands of arborvitae. Damage to ornamental plantings occurred in Berkshire County in 1995, and in 1997 defoliation was common, particularly in western Massachusetts.

Black Turpentine Beetle, *Dendroctonus tenebrans*, found in the eastern half of the United States, attack pines and spruces, often trees in weakened condition. Beetles are reddish-brown to black, less than 1/2 inch long. Eggs are laid on the lower portion of trunks and larvae tunnel into the cambium and kill portions of the bark. The black turpentine beetle infested 230 acres in 1979 in Falmouth, Chatham, and Nantucket. Many pines in these same areas were dead or dying in 1983 as a result of beetle attack.

Hemlock Leaf Miner, *Coleotechnites apicitripunctella,* occurs in Quebec and the Northeastern United States. Moths appear in summer and caterpillars mine into hemlock needles, and web them together forming nests in which they overwinter. Caterpillars resume feeding in the spring. Outbreaks occurred in Royalston and Northfield in 1980 defoliating 17,600 acres of hemlocks.

Red Pine Sawfly, *Nediprion nanulus*, attacks mature needles of red pines. Egg hatch in May, and gregarious larvae, which reach nearly one inch in length, feed on mature needles. Since larvae consume mature needles, trees can withstand feeding unless defoliation occurs for several successive years. Defoliation of red pines occurred in Framingham and Natick in 1943.

Chapter 15.
Major Tree Diseases

Dutch Elm Disease fungus, *Ceratocystis ulmi*, first found in Ohio in 1930, spread to Massachusetts by 1941. European bark beetle, *Scolytus multistriatus*, first discovered in Boston in 1909 is the principal vector of the disease. Beetles feed on young twigs of elm in spring. Beetles that emerged from diseased trees carry spores of the Dutch elm disease fungus. The infection of healthy trees occurred during this spring feeding activity. This commensal activity of the fungus and the beetle caused the demise of the elm in North America, despite efforts to save this stately tree.

The responsibility for control of Dutch elm disease in Massachusetts transferred from the Department of Agriculture to the Department of Conservation in 1949. Legislation passed in 1952 required the Department to cooperate with towns and assist with surveys and removal of diseased trees. Property owners were required to remove diseased elms within 500 feet of a public way, an economic burden few could afford. Towns and cities could not keep up with the removal of dead and dying elms. Trees not destroyed provided foci for beetles and the continuation of the rapid spread of Dutch elm disease.

Surveys by Bureau personnel demonstrated the rapid spread of the disease; from 1954 to 1955, there was a five fold increase in diseased elms. Bureau personnel took branch samples to the Shade Tree Laboratory at the University of Massachusetts, Amherst, to verify the presence of the disease. The Bureau provided up to four crews and equipment to assist municipalities with surveys, removal of diseased elms, and spray programs.

The short period that the beetles are active before laying eggs limited the effectiveness of insecticides. The use of DDT was replaced with methoxychlor. The Bureau cooper-

ated with the Shade Tree Laboratory to test a systemic insecticide, Benomyl, for beetle control in 1972.

The most effective method of control was removal and burning or burying diseased and dead elms to kill beetles and eliminate breeding sites. Cost of tree removal in 1972 ran as high as $400 to $500 per tree. The increase in prohibitions of open air burning or burying trees in landfills compounded the problem of elm disposal.

Unprotected elms in woodlands, mostly in moist areas near streams, were killed by the disease. Control measures allowed many municipalities that valued elms to delay the onset of the disease but most could not afford the financial burden; ultimately, the disease eliminated elms.

Chestnut Blight Fungus changed forever the composition of Massachusetts forests, by eliminating one of the dominant and most valuable tree species, the American chestnut. The wood, less susceptible to rot, was used extensively for construction of buildings, bridges, furniture, and railroad ties. The edible nuts were harvested and also provided a valuable food resource for wildlife.

Chestnut blight was first reported near New York City in 1904 and reached Massachusetts by 1909. A 1911 survey by the U.S. Department of Agriculture found the blight in 72 Massachusetts towns. By 1914, the disease occurred nearly everywhere chestnut grew in the State. The rapid spread and death of trees indicated that chestnut would be lost, and trees were harvested for lumber. Sprouts of chestnuts from the old, living rootstocks can still be found, but are killed by the blight fungus, usually before they reach several inches in diameter.

White Pine Blister Rust, another fungus disease, apparently entered Massachusetts on a shipment of a half million white pine seedlings from Germany. The rust requires alternate hosts,

wild currants and gooseberries (*Ribes*), to complete its life cycle. Spores spread to, and can kill the primary host, white pine.

The State Nursery Inspector's survey for white pine blister rust in 1912 found it in Hamilton, Ipswich, Westminster, Spencer, and the Housatonic Valley. The disease spread rapidly, infesting all towns east of the Connecticut River by 1921. White pine blister rust spread from 124 to 236 towns between 1922 and 1928.

Recognizing the economic threat to the white pine, the State Forester recommended a policy to deal with the disease. The Legislature appropriated $27,000 in 1916, with an additional $10,000 added soon thereafter. The U.S. Department of Agriculture contributed $13,000, and in 1918 assumed the responsibility for control of white pine blister with assistance from the State Forester. An agreement signed in 1919 required the State to scout wild current and gooseberry. The control strategy was to stop the cycle of attack on white pine by eliminating the wild currant and gooseberry. The ambitious federal program used Civilian Conservation Corps and paid the State and landowners to scout and remove *Ribes*.

The white pine blister rust was the longest continuous cooperative program between Massachusetts and the U.S. Department of Agriculture. By 1966, over 1.3 million acres had been scouted and *Ribes* eliminated, and there remained little evidence of damage to pines. The program, which required two full and two part time State employees, was terminated in 1968.

Suggested References. We gleaned most information from the annual reports to the Massachusetts Legislature of the agencies responsible for management of shade tree and forest pests, starting with the 1890 report of Board of Agriculture. Early information on the gypsy moth an browntail moth was from the excellent 1896 publication by Edward H. Forbush and Charles H. Fernald, The Gypsy Moth (Wright & Potter, Boston). Early records of the involvement of the U.S. Department of Agriculture, Bureau of Entomology were obtained from annual reports of L. O. Howard, A. F. Burgess, and C. M. Rogers. The most recent and comprehensive compilation of research on gypsy moth is in C. C. Doane and M. L. McManus, The Gypsy Moth: Research Toward Integrated Pest Management (U.S. Dept. Agric. Forest Service Technical Bulletin 1584, 1981).

Additional information on the browntail moth can be found in Population Ecology of the Browntail Moth (*Euproctis chrysorrhoea* L.) (Lepidoptera: Lymantriidae) in North America by P. W. Schaefer (Dissertation, University of Maine, Orono, 1974). Early records occur in Life History and Habits of the Imported Brown-tail Moth by C. H. Fernald and A. H. Kirkland (Wright & Potter, Boston, 1903)

Information on biology and hosts of forest insects appears in Eastern Forest Insects by W. L. Baker (U.S. Dept. Agric. Misc. Publ. No. 1175, 1972) and W. T. Johnson and H. H. Lyon, Insects That Feed on Trees and Shrubs (Cornell University Press).

Information on biological control appears in Biological Control of Arthropod Pests of Northeastern and North Central Forests in the United States *A Review and Recommendations* by R. G. VanDriesche, S. Healy and R. C. Reardon, (U.S. Dept. Agric. For. Serv. FHTET-96-19, 1996).

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Dedication. We dedicate this publication to those employees, past and present, who served the Commonwealth of Massachusetts with their efforts to survey, study and share information on pests, introduce and monitor exotic parasites, predators and diseases for biological control, and when necessary, develop and utilize management strategies for forest and shade tree pests.

Authors' Profiles. David E. Leonard is Professor Emeritus, University of Massachusetts, Amherst. His research interests include introduced tussock moths. With many of his former graduate students, he has studied aspects of behavior, ecology, and physiology of the gypsy moth, Asian gypsy moth, rosy gypsy moth from the Russian Far East, browntail moth, and satin moth.

Charles M. Burnham has spent his professional career with the Department of Environmental Management and has been involved with many of the pest management programs for forest and shade tree pests. As Supervisor, Forest Health Program, he is responsible for pest surveys, the monitoring and management of insect pests of forest and shade trees in the Massachusetts State Forests and Parks System, and for providing information and assistance to municipalities.

Appendix 1. Defoliation by gypsy moth in Massachusetts from ground and aerial surveys. The 1988 figure represents an incomplete aerial survey due bad weather. Insecticide treatments reduced defoliation in some years.

1924	163	**1945**	456,832	**1966**	500	**1987**	16,007
1925	48,321	**1946**	217,132	**1967**	909	**1988**	5,273
1926	78,193	**1947**	7,256	**1968**	3,925	**1989**	6,618
1927	131,880	**1948**	32,386	**1969**	6,060	**1990**	83,595
1928	137,121	**1949**	78,665	**1970**	6,835	**1991**	282,143
1929	95,078	**1950**	4,979	**1971**	18,787	**1992**	123,794
1930	27,856	**1951**	3,185	**1972**	20,480	**1993**	88,684
1931	86,694	**1952**	83,372	**1973**	3,970	**1994**	79,695
1932	200,387	**1953**	917,996	**1974**	6,903	**1995**	8,101
1933	157,003	**1954**	118,095	**1975**	17,895	**1996**	6,960
1934	128,237	**1955**	-	**1976**	9,820	**1997**	115
1935	106,097	**1956**	3,830	**1977**	133,081		
1936	152,469	**1957**	16	**1978**	63,042		
1937	393,613	**1958**	8	**1979**	226,220		
1938	154,348	**1959**	382	**1980**	907,075		
1939	143,292	**1960**	150	**1981**	2,826,095		
1940	125,586	**1961**	3,000	**1982**	1,379,735		
1941	263,369	**962**	150,000	**1983**	217,548		
1942	36,715	**1963**	87,847	**1984**	308,599		
1943	34,481	**1964**	20,787	**1985**	477,805		
1944	225,637	**1965**	17,232	**1986**	404,538		

Appendix 2. Parasites and a predators collected in the native ranges of the gypsy moth and browntail moths and released successfully in Massachusetts as biological control agents for gypsy (gm) and browntail (btm) moths.

Name	Type	Host	Stage Attacked	Established
Anastatus disparis	Parasitic wasp	gm	Egg	1909
Anastatus disparis	Parasitic wasp	gm	Egg	1909
Blepharipa pratensis	Parasitic fly	gm	Caterpillar	1909
Calosoma sycophanta	Predaceous	gm	Caterpillar, beetle Pupa	1909
Compsilura concinnata	Parasitic fly	gm,btm	Caterpillar	1906
Bracyhymeria intermedia	Parasitic wasp	gm	Pupa	1960's?
Cotesia melanoscela	Parasitic wasp	gm,btm	Caterpillar	1914?
Cotesia lacteicolor	Parasitic wasp	gm,btm	Caterpillar	1912?
Meteorus versicolor	Parasitic wasp	btm	Caterpillar	1915
Monodontomerus aerus	Parasitic wasp	btm	Caterpillar	1909
Ooencyrtus kuvanae	Parasitic wasp	gm	Egg	1909
Parasitegena pratensis	Parasitic fly	gm	Cat rpillar	1910?
Townsendiellomyia nidicola	Parasitic fly	btm	Caterpillar	1915

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